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PROCESS ENERGY INVENTORY AT KANSAS ARMY AMMUNITION PLANT

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Detailed energy audits were performed on each of the processes involved in the production of 155 mm M483 ICM rounds at the Kansas Army Ammunition Plant. Energy consumption baselines were established for all of the individual operations associated with this round, and potential energy conservation opportunities were defined, which amount to $3,495 per year under the current one-shift-per-day operating level and $9,635 per year under a three-shift-per-day operationing level. Reviewed are the principal advantages and disadvantages of air logics and intrinsically safe logics when used for medium-sized control functions.

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Mohammad Mortazavi, Former Kansas AAP Energy Coordinator

SUMMARY

This engineering evaluation established the baseline energy use for each process involved in the production of M483 155 mm ICM rounds by the 300 Area Production Line at Kansas Army Ammunition Plant based on current production practices and energy types and costs. This baseline is the summation of all electrical demands including the air compressors serving the air-powered process equipment. The current production schedule of 750 completed rounds on a single eight-hour shift requires a total of 1,622 KWH with 376 KWH used for process air production. At 4.00¢ per KWH a total cost per round of 8.65¢ is indicated, with 2.01¢ of that being required to supply compressed air.

Several specific recommendations have been formulated for actions to reduce current total energy use of the 300 Area processes. A number of general recommendations are included relative to minor changes practicable at this time and changes that could be effected at the time modifications are made to the existing equipment. Modification of the existing hydraulic systems in the packout area is a major recommendation, but it may be affected by final design limitations. Many of the electric motors used can be operated more efficiently through the application of power factor corrections. The recommendations delineate these energy conserving alternatives and the associated predicted payback periods.

This report also reviews the principal advantages and disadvantages for air logics and intrinsically safe logics when utilized for an existing medium-sized control function. The work station selected was a grenade layer insertion system used in the packout area.

FOREWORD

In the early 1950's, this nation's demand for petroleum began to outpace its supply. Consequently, it began to import crude oil from foreign sources. This imbalance between internal supply and demand continued to increase until, by 1973, nearly 30% of all domestic consumption was supplied by foreign imports. During that year the Organization of Petroleum Exporting Countries (OPEC) imposed an embargo on crude oil shipments to the United States, causing severe hardships in both the industrial and private sectors. Even though the embargo was short-lived, it did have far reaching consequences, namely (1) the rapid escalation of fuel prices, and (2) the creation of a nationwide awareness that fuel supplies are very uncertain and subject to instant interruption. In spite of this occurrence, the foreign oil dependency has been allowed to escalate to the point where nearly 50% of the United States' requirements are now imported.

Because of the above fuel situation, there is reason for concern that energy in appropriate quantities may not be available in the future to meet mobilization requirements at the Army's manufacturing and loading plants. Even if these requirements can be satisfied, it is certain that manufacturing costs will be adversely affected by rapidly escalating fuel prices. To insure that mobilization requirements can be met at an economically acceptable level, it became evident that a comprehensive energy conservation program would have to be established. MMT Project 4281, "Conservation of Energy at Army Ammunition Plants," was established to introduce advanced energy conservation technology into the process operations at munitions plants.

This report describes the process energy inventory portion of Project 4281 that was conducted at Kansas Army Ammunition Plant, Parsons, Kansas by Day & Zimmermann, Inc. The purpose of this work was to thoroughly define the process energy requirements on one energy intensive production line and to identify cost effective measures which could be taken to reduce energy usage. This work was done on a unit process basis for the 300 Area Production Line, by the use of energy measurement and comprehensive analytical techniques.

This report identifies a number of general and specific energy conservation opportunities which can save \$3,495 per year under current (one shift per day) operating level and \$9,635 per year under a three shift per day operating level. These savings represent a 20% reduction in process energy requirements. Implementation costs and payback times are discussed for all of the specific recommendations.

The Special Technology Branch, Energetic Systems Process Division, LCWSL, ARRADCOM was responsible for the assignment of funds and technical direction of the project effort documented herein.

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INTRODUCTION

The Kansas Army Ammunition Plant was built in 1941 and 1942 as a loading plant for shells, bombs and component parts. It is located in Labette County, Kansas, approximately two miles east and one mile south of Parsons, Kansas. The plant is a Government-owned Contractor-operated (GOCO) military industrial installation under the jurisdiction of the Commanding General, Headquarters, Department of the Army Materiel Development and Readiness Command, Alexandria, Virginia. However, effective 1 July 1973, command jurisdiction and responsibility for the Kansas Army Ammunition Plant were transferred from HQ, U.S. Army Armament and Supply Agency (APSA), Joliet, Illinois, to the U.S. Army Armament Materiel Readiness Command, (ARRCOM), Rock Island, Illinois, a subcommand of the Department of the Army Materiel Development and Readiness Command (DARCOM).

When the production lines at Kansas Army Ammunition Plant were devised, energy saving technology was not a major factor for consideration because cheap energy supplies did not warrant the additional expense that would have been required to achieve it. Consequently, energy conservation measures were not employed in the original process designs except in cases of severe energy waste. The rapid escalation of energy costs over the past several years, however, has created the need for a reexamination of this philosophy to determine if the incorporation of energy conservation technology in process operations is now worthwhile.

The objective of this engineering evaluation was to respond to the aforementioned need by performing a process energy audit on one of the production lines at Kansas Army Ammunition Plant. The ultimate goals were to establish a process energy baseline for each operation used, identify feasible procedural changes, and to the extent reasonable, develop cost estimates and work plans for implementing economically justifiable energy conservation measures. Comparison of air logics and intrinsically safe logics was to be performed for a selected assembly process.

PROCESS SELECTION AND DESCRIPTION

The 300 Area Production Line has been identified as the largest process energy user which is now in operation. Consequently, it was selected as the focal point for the audit work described in this report.

The 300 Line was originally released to the operating contractor in early 1942 and was used to Load-Assemble-Pack (L/A/P) fuzes for various artillery shells. At the end of the World War II emergency, the line was placed in layaway in late 1945. It remained in a laidaway state until reactivation for the Korean conflict in 1951 when it was again used to L/A/P fuzes for various shells. After the Korean Peace Treaty was signed, production gradually decreased until the line was again placed in layaway in 1956. It remained in a laidaway state until 1967 when this line was chosen as the site for the L/A/P operation for the gravel mine. Construction began in 1967 to modify the production buildings to perform this operation. Then in 1968, the gravel mine item was discontinued and the line was placed in layaway again. Partial construction was completed; however, the line was laidaway with the major part of the construction yet to be completed. The line remained laidaway until 1974 when it was selected as a site for the L/A/P of the M483/M509 155 mm ICM round. Construction began in 1975 to modify the production buildings to perform this mission. Much of the construction accomplished in 1967 was utilized in the modification and equipment installation for the production of the new item. Construction and modification was completed in June 1976 and initial production was accomplished in October 1976. This production line has remained in an active status producing the M483 155 mm ICM round since 1976.

The production steps for L/A/P of the M483 155 mm ICM round are as follows: 1) Hardness Test - the M42 and M46 grenade bodies are tested for proper hardness and for metal continuity. If the grenade bodies are not of the proper hardness and contain cracks or weak spots, they are rejected. 2) Lead Insertion and Foil Insertion - the lead cup is placed in the top of the grenade and a foil disc is placed on the inside of the grenade which covers the exposed powder in the lead cup to eliminate contact of the powder in the lead cup and the powder which will be loaded into the grenade body. 3) Body Load - the Composition A-5 explosive is loaded into the M42 and M46 grenade bodies and the armor-piercing cone is swaged into place. 4) Initial Assembly - the fuze is placed upon the grenade body and the arming ribbon is put into place. 5) Final Assembly - the completed M42 and M46 grenades are loaded into the 155 mm round. Eleven rows of eight grenades are loaded in each 155 mm round. The base plug is then put into place and an expulsion charge is placed into the nose of the round. The rounds are then packed for outshipment.

Drawings showing the layout of the 300 Area Production Line and production machines in Buildings 315 and 324 are included in this report (figures 1 through 4). Air compressors for 300 Line process use are installed in Buildings 315 and 328. In Building 315, the compressor room is located in the southwest corner of the packout area (not shown in figure 4).

INVENTORY METHODOLOGY

This engineering investigation was completed using a four-step procedure; study initiation; energy use data collection and analysis; alternate control logic system analysis; and energy conservation and control logic recommendation.

The effort was initiated by the selection of the 300 Area Production Line at Kansas Army Ammunition Plant for analysis, as described above. A survey was conducted of all 300 Line production processes to determine what types of energy are currently utilized and to select a typical station for use in the control logics comparison.

The predominant energy form was found to be electricity with a significant portion of its total consumption being utilized to operate the compressors providing the power for air-operated equipment. Instrumentation and measurement equipment required for the study was selected and obtained.

Process energy use data was collected by metering both electrical demand and air consumption of the 300 Line production equipment. This was carried out by metering each item or system of production equipment. Actual energy use required for cleanup and maintenance functions was not obtained as these are production support activities. Project Engineering, Line Maintenance, and Scale & Instrument Shop personnel were involved in the data collection phase of this study.

The alternate control logic analysis was initiated by surveying 300 Line production equipment to identify an operation that could best represent the feasibility of using an alternate logic control system.

Energy use data was evaluated by the Project & Facilities Engineering Division to develop recommendations for energy conservation options. Economic feasibility analysis was performed for both current schedule and mobilization production rates. These recommendations were merged with the control logic analysis findings to form this final report.

PROCESS AIR CONSUMPTION AND COST

Air Data Collection Procedures

Due to the range of air flow rates metered, it was necessary to use three flowmeters. The flowmeters and the flow rate monitor used were manufactured by Flow Technology, Inc. (FTI). An FTI model FTM-N10-GJS OMNIFLO turbine flow transducer was used for air flows in the range 0.03 - 1.25 actual cubic feet per minute (ACFM). An FTI model FT-8-8N7.5-GB standard line turbine flowmeter was used for flows of 9 - 90 ACFM. Product data for each flow measuring device is attached as appendices A and B.

A BLH type DHF high frequency pressure transducer (0 to 2,000 psig) was utilized in conjunction with a Daytronic Model 3370 transducer indicator. A standard laboratory thermometer was used for in-line temperature measurements. A 2-channel stripchart recorder was used for continuous pressure and flowmeter data recording.

The FT-20N90-GB was used only to meter compressor output. It was installed in the main airline in the compressor houses. A cumulative digital readout was checked at specified times to obtain actual total air consumption during each production and nonproduction period of the days monitored (2 October 1979 thru 5 October 1979 and 8 October 1979 thru 11 October 1979). Data obtained is shown in table 1.

Flowmeters FT-8-8N7.5-GB and FTM-N10-GJS were used to obtain data for actual air consumption of each production process. These meters were installed in a manifold system constructed by the Scale & Instrument Shop personnel (see figure 5). This system permitted accurate metering at the supply point to each work station. Each meter was installed in the manifold in accordance with the manufacturer's recommendations on inlet and outlet conditions. Actual connection and disconnection of the manifold system to the air supply line were performed by Scale & Instrument, Project Engineering, and Line Maintenance personnel. Data obtained is shown in table 2. Figures 6 and 7 represent the correlation between the meter reading and flow rate in ACFM for each meter. An example of a typical stripchart obtained using one of these flowmeters is provided (see figure 8).

In order to make meaningful comparisons between varying flow rates, it is necessary to express those flow rates in standard cubic feet per minute (SCFM). The flow rate in SCFM is equivalent to the flow rate that would occur if the actual air pressure was 14.7 pounds per square inch absolute (psia) and the temperature was 520 degrees Rankine (60 degrees Fahrenheit). As the flowmeters used in this engineering study expressed flow rate in ACFM, the following conversion equation was used to determine SCFM:

$$Qs = Qa \times {}^{Pa}/Ps \times {}^{Ts}/Ta$$

Where: Q_s = Air flow rate in SCFM
Q_a = Air flow rate as measured in ACFM
P_a = Measured air pressure in psia
P_s = Standard pressure (14.7 psia)
T_s = Standard temperature (520^oR)
T_a = Measured air temperature immediately downstream (^oR)

Summary of Air Data

The 300 Area Production Line at Kansas Army Ammunition Plant uses compressed air as part of the operation of most production machines. Operating at the current production rate of 750 each M483 155 mm ICM rounds per day (one eight-hour shift), the average demand for compressed air is nearly 200,000 standard cubic feet (scf) for a 24-hour period (see table 3). The predicted quantity of compressed air required to produce 750 rounds using the current operational practices is about 63,500 scf (see table 4) or about one-third of the daily total air consumption.

Actual air consumption (see table 1) and the corresponding production of grenades and completed rounds (see tables 5 and 6) were used to find the actual total daily air consumption, actual one-shift air consumption, and predicted process air consumption (see table 3). The predicted process air consumption was determined by estimating the daily air consumption of the work stations operating on the metered days. This involved calculating the air used during the total number of peaks required at each work station and adding that figure to that obtained by calculating the total non-peak consumption. Average values of peak period, peak usage, and non-peak usage (see table 2) were used.

Table 3 indicates that process air consumption represents about 41% of the air used during the production shift or only about 33% of the total daily air demand. The 300 Area Production Line maintains a rework operation and a maintenance shop, both requiring air from the 300 Line compressors. These functions and the typical air system losses account for the remaining air during the production shift. Nighttime cleanup and maintenance activities are responsible for the sizeable air demand between production shifts.

Air Consumption Analysis

The procedure for this engineering study suggested the formulation of a correlation between production units produced, energy consumed, and cost of energy. The energy consumed by process air is represented by the load on the electric motor on the operating air compressor. The compressor motors were metered on the same days as the air output was monitored. During this period, energy cost averaged $4.49 per hour during the production shift and $2.13 during non-production shifts based on a unit cost of 4¢ per kilowatt-hour (KWH). This indicated an average air cost of 23.7¢ per thousand standard cubic feet consumed (Kscf).

To compare current process air use and cost to that which should occur if ideal production could be achieved, four production rates were determined. Comparing the energy use at the current production schedule to theoretical maximum production levels will show what impact process machine cycling would have relative to energy use.

The current production schedule requires 750 completed M483 rounds per day (66,000 grenades required). One theoretical maximum production level would be 2,250 completed rounds per day based on three eight-hour shifts operating identically to the single eight-hour shift producing at this time. A total of 198,000 grenades would be required each working day.

Another theoretical maximum production level would require that the series assembly production in the packout area operate with no downtime at the machinery's design limit of two completed rounds per minute. This would indicate a theoretical maximum production of 960 completed rounds during a single eight-hour shift.

A third theoretical maximum production level can be determined by requiring all grenade processing equipment to operate ideally with no downtime. This would combine with the requirement that the series assembly production in the packout area also operate with no downtime. The maximum production rates of the grenade processing equipment operating at the machinery's design limits are as follows:

Hardness Testing, Lead Insert, Foiling (3 systems total) -	90 grenades/minute/system
Body Loading (3 systems total) -	90 grenades/minute/system
Assembly Machine (3 systems total) -	30 grenades/minute/system

The theoretical maximum production level of grenades obtainable from a single eight-hour shift is 129,600 (480 minutes at 270 grenades per minute). Matching this to the packout area's maximum demand of 176 grenades per minute of operation (88 grenades per round times 2 rounds per minute) indicates a packout time of 12.27 hours. For the purposes of this study, a slight reduction of maximum grenade production was used to permit complete packout in 12 hours. This would require 125,720 grenades to produce 1,440 completed rounds. Note that all areas, except packout, would operate on a single eight-hour shift.

Predicted process air consumption of each production area at each production level (see table 4) was determined by using the peak usage per cycle and non-peak usage (see table 2) and determining the total duration of non-peak production time. For 750, 960, and 2,250 rounds per day, it was assumed that two of the three systems available in the hardness testing, lead insert, and foiling area; two of the three systems available in body loading; and eight of the ten assembly machines would be used. For 1,440 rounds per day, all systems would be required.

As packout is a series assembly process, all work stations are required for each round. Spare units were neglected. The leak test operation is not normally used on every round, but it was considered as being used continuously for this energy analysis.

Table 4 is included to show the relative air consumption and energy cost of each production area at four production levels. Air consumption was calculated as described above. Energy cost was determined by using a flat rate of 23.7¢ per Kscf. Energy cost per round was found by dividing the total energy cost by the number of completed rounds produced. The term equivalent energy is used to indicate the electrical energy consumed by the compressor motor. The values shown in table 4 under this heading represent the energy used by a specific process as fraction of the total energy used by the production line. For example:

Total Air Consumption = 63,490 SCF

Total Air Energy Use = 376 KWH

Assembly Machines Air Consumption = 38,549 SCF

Assembly Machine Air Energy Use = $376 \times 38{,}549 \div 63{,}490 = 229$ KWH

The data contained in table 4 must not be misused. For example, the energy used by the projectile marking process in packout is shown as 21 KWH. If this process were to be eliminated entirely, the associated energy savings would not be 21 KWH but some amount less. This is due to the fact that the compressor operates less efficiently as the load drops. It is important to remember that the average compressor energy cost was $4.49 per hour on the days monitored and that when the compressor load was effectively eliminated, the energy cost still averages $2.13 per hour. Using a flat rate of 23.7¢ per Kscf to calculate energy savings would generate inaccurate conclusions.

Figure 9 shows the comparative air consumption of each production area as compared to total process air. Air energy cost by area would maintain the same ratios. Figure 9 indicates that the assembly machine area is the largest air consumer. The hardness testing, lead insert, and foiling area ranks second in air consumption. The body loading area ranks third.

Figure 10 shows the comparative air consumption of each process involved in the packout area as compared to total air consumption of the packout area at either current or three-shift production levels. Air energy cost by process would maintain the same ratios. The consumption shown for the grenade layer insertion process is the total for the 11 machines required. Minimal changes occur when production increases to 960 and 1,440 rounds per shift.

Figure 10 indicates that the projectile marking machine is the only single machine in the packout area using a significant volume of air. The combined demand of the 11 load insertion stations is the only other instance where economically justifiable air-related energy conservation measures might be taken. These two functions represent 5.6 and 3.9 percent, respectively, of the total 300 Line process air.

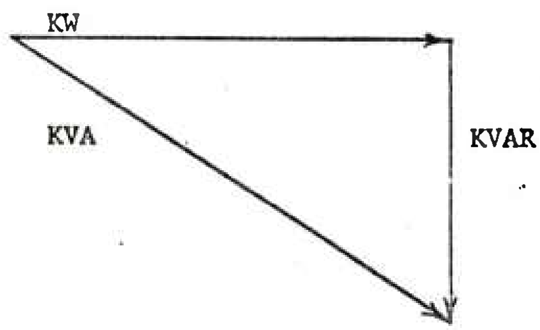
Terminology

Definitions relating to process electrical demand are:

KW - Kilowatt. This is the real power or the power that actually performs the work done by the electrical circuit. A wattmeter acknowledges only this part; that is, the current component that is in phase with the applied voltage or the current flowing through the resistance in the circuit.

KVAR - Kilovolt Amperes Reactive. Also known as "phantom power". It provides the magnetization force necessary for operation of the work performing device. Current flowing in magnetic devices lags the applied voltage by 90 electrical degrees. The cause is self-induction, a condition inherent in all A-C magnetic devices. Rise and decay of alternating current in the magnetic device induces a voltage and accompanying current, which opposes the force creating it.

KVA - Kilovolt Amperes: Heating developed in components of the distribution system is caused by the resultant of KVAR and KW; this quantity is known as kilovolt amperes. This quantity is also known as apparent power. All components of the distribution system - back to and including the utility company's generating equipment - must be sized to carry the KVA of the system. The relationship of KW, KVAR, and KVA in an electrical system can best be illustrated by scaling vectors to represent the magnitude of each quantity, with the vector for KVAR at a right angle to that of KW. When these components are added vectorially, the resultant is the KVA vector.



Power Factor. The angle between the KW and KVA vectors is known as the "phase angle", and is used as a measure of the relative amount of KVAR in the system. The quantity known as "power factor" is simply the cosine of this angle, or KW/KVA. As the amount of KVAR is decreased, the phase angle is diminished, and the magnitude of KVA approaches that of the KW. When this phase angle decreases to zero, power factor becomes 1.00 or 100 percent. At 100 percent (unity) power factor, KVA is equal to KW, and all of the heating developed in the system is a function of current that is actually performing work.

Power Factor Improvement Capacitors. Current through a capacitor leads the applied voltage by 90 electrical degrees and has the effect of "canceling" or "absorbing" inductive (lagging) KVAR on a one-for-one basis. Benefits of this type improvement scheme are reduced voltage drop and current, increased distribution system capacity, as well as improved billing costs. Capacitors installed across the terminals of an offending motor will reduce current from that point all the way back through the plant distribution system.

Power Factor Control System for AC Induction Motors [Power Factor Controller (PFC)]. This invention is a solid-state device which senses the load on a motor and adjusts the voltage so that the power factor is at the best attainable value. This also reduces the current and losses due to current and voltage, resulting in significantly improved efficiency. The value of using a PFC for a particular application depends upon the load on the motor, the operating time, and electricity costs. The principle behind the PFC is that when electric motors operate at less than full load, the power factor becomes increasingly worse as the load decreases from full load to zero load. Power factor can deteriorate from around 85 percent to as low as 10 percent to 20 percent. The result is that input current is not proportional to load, but remains significantly close to full load current. The PFC essentially reduces the input voltage as the motor load is decreased, thus improving power factor and reducing current. Efficiency is improved by reducing core losses, which are proportional to the square of the current. A negative aspect of the PFC is that it tends to cause a slight speed reduction of the motor. Very little is said about the application of this device to motors on the 300 Line. This is due mainly to the unavailability of three-phase devices compatible with our motor sizes. This device definitely holds possibilities though, and we plan to conduct tests on one or more as they do become available.

Electrical Data Collection Procedure

Electrical data was collected utilizing a General Electric Model CH-7 portable recording voltammeter with hook-on current transformers, an amprobe clamp-on ammeter, and a General Electric Model CH-11 portable polyphase watt/VAR recorder with hook-on current transformers. An example of a typical stripchart is provided (see figure 11).

Each production process was monitored separately to find kilowatt demand and power factor. The two 300 Area Production Line air compressors were monitored separately during the period 2 October 79 thru 11 October 79. Data obtained is shown in tables 7 and 8.

The power factor of each three-phase circuit was determined using the nomograph method. The nomograph used was provided as a part of the CH-11 recorder. Watt and VAR values from the stripchart were used in the calculations.

Total 300 Area Production Line electrical demand is metered continuously through the permanent installation of a General Electric Model V-65-S cumulative kilowatt-hour metering station in the primary, three-phase 12,570 volt supply lines. Monthly totals and the approximate average daily demand is shown in table 9.

Summary of Electrical Data

All production areas of the 300 Area Production Line are dependent upon electricity. Operating at the current production rate of 750 M483 155 mm ICM rounds per day (one eight-hour shift), the average daily demand for the entire 300 Area is about 5,700 KWH (see table 9). The process related electrical demand during the eight-hour production shift (750 rounds) is about 200 KW or 1,600 KWH (see table 10). Lighting and air conditioning loads for the production buildings were not determined but would represent a large portion of the remaining electrical demand. Electrical equipment and miscellaneous uses in other 300 Area buildings were not monitored as they are not an integral part of the manufacturing process.

Table 7 includes electrical demand and cost data for the three grenade processing areas. Operating power factor for each three-phase system is also provided. A comparison of actual current required and that indicated on the motor nameplate is shown. Table 8 provides similar information for the packout area functions and the compressor houses.

Table 11 provides a breakdown of the electric motors used by complex systems, such as body loading. Values shown in tables 7 and 8 are based on the combined load in multi-motor systems.

The expected total electrical demand for the 300 Production Line processes at varying production levels is provided in table 10. These figures are based on the summation of air compressor electrical costs and process machinery electrical costs. A description of each production level and the process machinery required for each level was discussed above.

The process machinery electrical demand of each production area is shown in figure 12 as a fraction of the total for the four areas. The packout processes account for approximately 40 percent of the total demand. Another 35 percent is used by the body loading systems. The assembly machines and the hardness testing, lead insert, and foiling operations require only about 20 percent and 5 percent, respectively.

Figure 13 shows the total energy consumption (air and electrical) by production area for varying production levels as a fraction of the total for the four production areas, including the air load of each area. Packout, assembly machine, and body loading functions have nearly equal energy demands which when added together consume more than 90 percent of the total for all processes.

Electrical Demand Analysis

The process machinery electrical demand is principally due to the large number of electric motors required to operate the machinery. Most of the motors used on the 300 Area Production Line are selected on the basis that they meet Class 1, Group D, Class II, Groups F and G, explosion proof ratings. Energy efficiency was not a prime selection consideration for the motors currently in use. Each motor is sized to match a specific mounting configuration and to fit in the space allowed. The cost of labor to modify the existing equipment to accommodate a more energy efficient motor would generally far outweigh energy savings. The replacement of motors with high efficiency models before normal replacement is due can not be justified based on energy savings.

Little energy conservation can be effected in the hardness testing, lead insert, and foiling area by making motor modifications due to the small number of motors in service. Normally, only two of the three principal systems are operated which further reduces potential savings in that the payback period for each system is extended.

The body loading systems exhibit a fairly high rate of electrical power consumption due to the large number of motors composing each system. The body loading systems use more motors than any other process system involved in the 300 Area Production Line. By observing the low power factors and comparing the nameplate full load current to measured current, it is evident that these systems are relatively inefficient. Application of power factor correction capacitors appears to be the only economically feasible energy conservation measure due to the configuration and design of the system. Even this improvement is limited to the two 15 HP hydraulic pump motors in each system. This could provide a 10 percent power reduction on each motor.

The instrumentation and controls of the three body loading systems could be connected to a single 3 KVA Sola transformer to provide regulated 120 VAC power, but this is not recommended. A single transformer would have adequate capacity but could introduce many problems between the individual systems. Circulating currents, noise, interference, transient voltage spikes, spurious signal recordings, and equipment shutdowns are problems that would definitely be expected to occur. The control circuits and the safety shutdown circuits are, of necessity, very sensitive and thus extremely responsive to voltage spikes or transients. Lost production time and various other equipment problems would far outweigh the small power losses internal to the Sola transformers.

The electric motors on the assembly machines fall into the same category as those for the body loading systems. The cost of labor to modify the equipment would outweigh any energy savings. Adding a capacitor to the 2 HP motor could result in a 15 percent reduction in power or about 500 watts.

Each assembly machine has its own Sola transformer to supply 120 VAC regulated power for instrumentation. Some savings would result in serving multiple machines from one transformer. The ways and types of instrumentation being utilized do not lend themselves to the problems that would be encountered in the body loading system.

The packout area provides the most opportunity to develop economically feasible energy conservation recommendations. Two prime opportunities exist. Some of the hydraulic pump motors might be made more efficient through the application of power factor correction capacitors or power factor controllers (PFC). Combination of hydraulic systems is another alternative which may provide sufficient energy savings to permit economic payback within a reasonable period of time.

Improved energy efficiency of the 300 Line air compressors could be very beneficial. Addition of power factor correction capacitors is feasible for existing equipment. Changing to synchronous motors rather than induction motors when replacing units is another alternative. At this time, manufacturers seem very reluctant to use synchronous motors. The initial cost is greater than that of the induction type and is physically somewhat larger. In the long run, the synchronous motor will offset the higher initial cost through lower energy demand costs.

CONTROL LOGIC ANALYSIS

Work Station Selection

For the purposes of this engineering study a work station on the 300 Area Production Line was selected which represented a medium-sized control function. The system selected could be controlled by either air logics or intrinsically safe logics. A grenade layer insertion system was selected.

These stations are used in the series round loading operation in the final packout area (figure 4, item No. 3). The principal function of each of these stations (load insertion station) is to push each layer of clustered grenades into the shell body and remove the safety pins. There are 13 identical stations of which 11 are used continuously to insert the 11 layers of grenades. The additional stations are currently installed to prevent downtime in the series loading operation and also for use on the M509 8-in.projectile,which uses 13 layers of grenades.

The existing equipment is powered by hydraulics and controlled by Dynamco moving part air logics. It was recognized that electronic control system energy use could be reasonably calculated, but that air control system energy use could not be calculated exactly because of normal air leakage through air logic control components. Therefore, the existing air circuit was metered and the energy use of logically equivalent electronic circuits was calculated. Explosion proof requirements for ammunition production were considered in the selection and pricing of control system alternatives.

Intrinsically Safe Logics Analysis

Two electronic control methods were investigated. An electronic, solid state, hard-wired system could be used to control the operation of a grenade layer insertion system. Similarily, a microprocessor based, software-controlled system could be used. Either system would require a minimal level of operational energy.

A solid-state equivalent circuit was designed to perform the control functions presently using air logics. Figure 14 shows the design of a solid-state load insertion station circuit. Figure 15 shows the design of the air logics circuit in place currently. The electronic circuit was designed, the power requirements calculated, and the design and construction costs estimated.

The solid state, hard-wired system would be a task-specific circuit and, therefore, virtually a one-of-a-kind item. This necessitates having additional exact replacement modules and highly trained maintenance technicians to troubleshoot operational problems of the circuitry. Accurate printed circuit schematics would need to be maintained. Changes to the system "program" require changing the physical wiring or interconnection of the logic components.

Approximately 3.2 amps of current at 115 VAC (370 W) would be required to actuate the solenoids controlling the hydraulic valves in the grenade layer insertion system. These valves control movement of the clamping head, tray, shot pins, and pallet. The control logic integrated circuits would consume an additional 30 W for a system total of 400 W. At $0.04 per KWH, this represents an operational energy cost of $0.016 per hour.

The projected cost to build the solid state, hard-wired system is $3,500 based on February 1980 component prices. This does not include auxiliary equipment such as test fixtures and instruments and spare replacement modules. Costs associated with completing and debugging the interface with the mechanical components are not included.

The microprocessor based, software-controlled system would permit more flexibility than would the solid state, hard-wired system. A programmable controller, such as the Allen-Bradley model PLC-2, could perform the required control functions. Some of the advantages are ease of troubleshooting and isolating problems which can be performed by competent technicians following a minimum of special training. Digital, electronic, solid-state industrial programmable controllers are designed for applications such as machine tool control, palletizing, measurement, and gaging. Programming and logic flow are similar to other logic control systems. However, the initial cost dictates that such programmable controllers not be used for simple functions that could be performed as well by less expensive alternate control mechanisms. Decision points based on cost depend on the number of input and output functions and the complexity of the logic decision functions.

Programmable controllers are modularized to permit rapid replacement of a faulty controller to minimize system downtime. The availability of off-the-shelf replacement modules, the product support and technical assistance generally available from factory-trained specialists, and the ease of logic modification (reprogramming) are advantages of utilizing microprocessor based, software-controlled systems.

The operational energy requirement for a programmable controller, such as the Allen-Bradley model PLC-2, is only slightly larger than that for the solid state, hard-wired system described earlier in this report. A total of 450 W is required due to the 370 W load of the solenoids and the 80 W input needed by the controller. At $0.04 per KWH, this represents an operational energy cost of $0.018 per hour.

The cost estimate for a programmable controller, to use on a grenade layer insertion system, is $8,000 based on the same criteria as was used for the solid state, hard-wired system.

Either of the two intrinsically safe control methods above could perform the control functions for a grenade layer insertion system. Maintainability related costs and ease of reprogramming are important advantages of microprocessor based, software-controlled systems. Initial cost is the principal advantage of solid state, hard-wired systems. For either system, operational energy cost is insignificant.

Air Logics Analysis

The existing grenade layer insertion system uses an average of 0.47 SCFM of air during continuous operation at an average cost of $0.237 per Kscf for an operational cost of $0.007 per hour. The machine logic is assembled from Dynamco moving part air logic standard components. The estimated cost as of February 1980 to have the control logic circuit designed and assembled is approximately $5,150. The Dynamco moving part air logics relays have proven to be reliable.

Air logics are easily and quickly analyzed and repaired in the automated production environment, with a minimum of equipment and minimum skill. The control circuit can be altered easily for small variation in operation. This is, however, both an advantage and a disadvantage because the alteration can be performed by unauthorized personnel.

Control Logic Alternatives

For the machine studied, directly converting the air logic to electronic logic, the machine using air logic consumes less operational energy than the electronic equivalent. The primary energy use of the electronic circuit is to power solenoids on hydraulic valves. The electronic circuit could possibly be optimized to use less power. In either case (air or electronic), the energy use for machine control is negligible. It should be noted that the bulk of the energy used by the electronic systems is consumed by the actuating devices and not the logic devices.

The hard-wired electronic control system can quickly be repaired by simply replacing the entire control circuit board. In-depth analysis and repair of the defective board can then be accomplished on the work bench. This would, of necessity, require a complete set of spare boards. Troubleshooting of the main air logic control system does have to be done on the machine and would incur production downtime for that period of time. Troubleshooting of the auxiliary equipment (sensors, switches, etc.) on both the electronic and air control systems would incur production downtime, as both would have to be done on the machine. The hard-wired electronic circuit cannot be as easily altered for a small variation in operation. The hard-wired electronic circuit would be even more cost effective if many identical machines were to be used, although this is generally not the case in industrial facilities.

The microprocessor-based system is more expensive for the size system studied, but would be easily converted to alternate machine functions (small or large). Troubleshooting and repair of machine stoppages could be accomplished quickly, but malfunctions in the electronic components would require replacement units be available.

As a general rule, it can be said that the service life of mechanical devices is limited, whereas electronic devices have no such life limit since there are no moving parts and therefore virtually no wear. Electronic devices have their own source of mortality, however, such as current surges and defective packaging. The mean time between failure (MTBF) for electronic devices is higher than for mechanical devices and, therefore, the maintenance costs are considerable lower. However, this is tempered by the need for minimum personnel and equipment and training costs for air systems.

ENERGY CONSERVATION OPPORTUNITIES

This project has resulted in the identification of numerous energy saving concepts which can potentially be cost effectively applied to the 300 Line manufacturing operations. These concepts are described below and are summarized in table 12. The cost effectiveness of these opportunities was based upon typical energy costs of 4¢ per KWH for electricity and 23.7¢ per Kscf for process air. At the current production level of 750 rounds per day, this equates to a total daily process energy cost of approximately $65 with approximately $15 of that directly attributable to process air requirements. Actual economic impacts of system modifications should be somewhat similar to that indicated in the following opportunities. However, prevailing energy costs, process requirements, and production schedules could have substantial impact on the individual analysis of each system's economics at the time of modification initiation to the extent that some of them would no longer be feasible or, possibly, that other system modifications currently not being recommended could be worthy of further study.

It is important to note that the opportunities and associated cost figures described below are based on several simplifying assumptions. Two cautionary statements are warranted: (1) Hydraulic system modifications may be limited by final designs and by other factors not specifically related to energy uses. (2) Application of power factor controlling devices is also limited. There is a point of no return on the total capacitance that can be added to the distribution system. As capacitors are added to motors, the plant electrical system power factor must be monitored carefully to avoid exceeding the 100 percent value.

The opportunities are as follows:

General Opportunities

Routine maintenance and operating procedures can have significant impact on total energy use. Review of these procedures by 300 Line pesonnel would ensure that adequate emphasis is placed on energy conservation. Shut-off valves are currently installed in the supply lines to all individual process systems. Routinely closing these valves during periods of non-production, e.g. lunch time, would reduce air consumption with no additional expense. Any airleaks in the system should be repaired immediately. Utilizing the more energy-efficient compressor of the two serving the 300 Area Production Line more than the less energy-efficient compressor is another simple, logical practice.

When modifications are made to the current production equipment and the related air and electrical systems, increased emphasis should be placed on energy requirements. Replacing the current air compressors with improved screw-type models that are more energy-efficient, quieter, and require less maintenance is recommended. Careful review of design plans is encouraged to ensure that air and electrical supply systems are as energy-efficient as practical. The power factor of electrical equipment being purchased should be monitored such that a general improvement of 300 Line power factor will be achieved. The addition of power factor controllers and power factor correction capacitors should be considered, where applicable. Consideration of hydraulic system improvements would also tend to reduce the total 300 Line energy demand.

It is estimated that the adoption of these general opportunities will result in about a five percent reduction in process energy consumption which equates to an annual savings of about $850 under a one-shift-per-day operating level and $2,550 under a three-shifts-per-day operating level.

Specific Opportunities

Hardness Testing, Lead Insert, and Foiling

No economically justifiable system modifications, based solely on energy savings, could be identified.

Body Loading

Installation of power factor correction capacitors on the two 15 HP hydraulic pump motors in each system is recommended. A total of approximately 10 KW could be saved by the 6 motors in this area. The capacitor purchase and installation cost is estimated at $500 per system. Approximately $265 per year could be saved per system at the current operating schedule of 750 rounds per day. These savings would double to approximately $530 at a three-shift (2,250 rounds) schedule. This indicates a payback period of 1.9 years at the current schedule and 0.9 years at the three-shift rate. Under one-shift-per-day and three-shifts-per-day operating levels, two and three systems are used respectively. The total estimated savings that can be expected from this change are $530 (single shift) and $1,590 (three shifts).

Assembly Machines

It is possible that at some point economic justification could be achieved for installation of power factor correction capacitors on the 2 HP drive motors. A current recommendation involves addition of capacitors on the 5 HP drive motor in each system. The cost per system is approximately $130 with a 2.6 or 0.9 year payback period based on annual savings of $50 (one shift) or $150 (three shifts). Under one-shift-per-day and three-shifts-per-day operating levels, eight and ten systems are used respectively. The total estimated savings that can be expected from this change are $400 (single shift) and $1,500 (three shifts).

Packout

Conveyor System No. 1 (East). Capacitors would reduce electrical demand by approximately 1.5 KW. This represents an annual savings of $125 (one shift) or $375 (three shifts). The payback period is estimated at 2.4 and 0.8 years, respectively, based on a cost of $300.

Conveyor System No. 2 (West). Capacitors could reduce electrical demand by approximately 1.0 KW. This represents an annual savings of $85 (one shift) or $250 (three shifts). The payback period is estimated at 1.8 and 0.6 years, respectively, based on a cost of $150.

Forward Plate Insertion, Grenade Layer Inserters, Shim Insertion, Gaging. The hydraulic pump motors used in these systems are loaded only during each brief work cycle, resulting in very energy-inefficient operations. During the peak work cycle, the motor current exceeds the name plate ratings. In the grenade layer inserters, this peak current increases as the number of grenade layers in the projectile increases. Modification of hydraulic systems is recommended such that one pump could supply two or more machines. A hydraulic accumulator could be used to smooth out the peaks of the systems joined. This should permit the elimination of seven 5 HP motors, effectively reducing energy use by approximately 37.8 KW. Hydraulic system modification cost and the related payback period is dependent upon the final design and, therefore, cannot be included in this report. Addition of capacitors to the remaining motors could further reduce electrical demand by approximately 4.9 KW. This represents an annual savings of $410 (one shift) or $1,225 (three shifts). The payback period is estimated at 2.5 and 0.8 years, respectively, based on a cost of $1,040.

Base Plug Torque and Detorque Machines. The operation of these machines dictates that each have its own separate hydraulic pump. Again, except for a short work cycle, the pumps are essentially unloaded. Adding a power factor correction capacitor to the base plug torque machine would result in an energy savings of approximately 1.6 KW. The detorque machine is not used on a continuous basis so it does not offer an economically feasible modification possibility. The 1.6 KW reduction represents an annual savings of $135 (one shift) or $400 (three shifts). The payback period is estimated at 1.9 and 0.6 years, respectively, based on a cost of $250.

Projectile Weigh Station and M483 Marking Station. The current demand of the hydraulic pump motors indicates that it may be practical to operate both systems from one pump also. An accumulator would be required to smooth out the demand peaks. Combining the systems would free a 10 HP motor or approximately 11.2 KW. Adding a capacitor on the remaining motor would further reduce consumption by another 1.25 KW. The 1.25 KW reduction represents an annual savings of $105 (one shift) or $310 (three shifts). The payback period is estimated at 1.4 and 0.5 years, respectively, based on a cost of $150.

Nose Plug Torque and Leak Test Station. As with the weigh and marking stations, the current demand on these pump motors also indicates the possibility of using one pump to supply two machines and adding a capacitor to the remaining motor to bring about a savings of 11.2 KW + 1.25 KW or 12.45 KW. The 1.25 KW reduction represents an annual savings of $105 (one shift) or $310 (three shifts). The payback period is estimated at 1.4 and 0.5 years, respectively, based on a cost of $150.

509 Transfer System. Although the length of hydraulic lines would be longer than for any of the other dual configurations, it appears that the on-and-off load mechanisms can be connected to the same pump. Because of this distance, two accumulators may be required. Possible energy savings by shutting off one motor and adding a capacitor to the other would be 11.22 KW + 1.25 KW or 12.47 KW. The 1.25 KW reduction represents an annual savings of $105 (one shift) or $310 (three shifts). The payback period is estimated at 1.4 and 0.5 years, respectively, based on a cost of $150. This system is not currently being used. Consequently, the above savings should not be considered as a potential savings opportunity under current operating conditions.

Building 315 Compressor. Addition of power factor improvement capacitors to the 125 HP motor could result in at least a 7 percent reduction in current demand or about 9 KW of power. This represents an annual savings of $750 (one shift) or $1,125 (three shifts). The payback period is estimated at 0.5 and 0.4 years, respectively, based on a cost of $400.

Building 328 Compressor. The 150 HP compressor already has power factor improvement capacitors in the circuit. A second compressor is currently being installed. It is a more efficient screw-type and it also will have capacitors.

Control Logic Opportunities

All control systems are similar in that they have input devices such as limit switches, pressure switches and push buttons; a decision making section such as relays (air or electric), solid-state devices, or controller with software; and the output which controls such things as solenoids, motor starters, or indicators.

Each type of control (air, solid state, and microprocessor based) has particular advantages and disadvantages in any application. The energy use of any type of control is insignificant when compared to the overall energy use of a production facility. Each machine control application should be evaluated by an engineer knowledgeable in all types of controls to ensure that the most cost-effective type of control which will satisfy the system requirements is applied.

CONCLUSIONS

The 300 Area Production Line at Kansas Army Ammunition Plant is a complex industrial manufacturing operation. The three grenade processing areas and the loading and packout area require sophisticated production equipment utilizing reliable and safe controlling and power supplying systems. Concern for minimizing process energy use is important but is somewhat offset by present energy costs and safety concerns. Operator safety is a major concern of this production facility.

Some reduction in total process energy use can be achieved immediately through implementation of the recommendations. Long-term benefits of this engineering study will become more evident as energy costs increase.

The review of alternative machine control systems provides information on the relative usefulness of both air logics and intrinsically safe logics. This inforamtion will provide assistance for activities involving machinery modification. The difference in energy efficiency between the two systems is minimal when compared with system design cost, construction cost, and maintainability. Therefore, energy efficiency is not a major economic factor.

Energy costs are still low compared to labor and material costs. After initial equipment design and construction, changes solely for energy conservation are generally not cost-effective or are not within the guidelines required by Army energy conservation programs (minimum dollar cost, payback, etc.). Increased emphasis must be applied during initial design of equipment to ensure that cylinders and motors are matched to the load, rather than oversized per common practice. Discretionary funds should be made available for small energy conservation actions which are outside of the parameters of major Army energy conservation programs.

RECOMMENDATIONS

As described in "Energy Conservation Opportunities" above and table 12, it is recommended that active consideration be given to:

1. The implementation of those energy saving modifications which promise satisfactory payback under the current one-shift-per-day operating level.

2. The initiation of additional investigations to define and implement those opportunities which cannot be characterized at this time (i.e., consolidation of hydraulic systems, use of more efficient logic control systems, etc.).

3. The establishment of plans for implementing the opportunities under a three-shift-per-day operating level.

Table 1. Metered air compressor output

DATE	TIME OF DAY	TIME PERIOD (MIN)	TOTAL AIR CONSUMPTION (ACF)	AVERAGE TEMPERATURE (^{o}R)	AVERAGE FLOW RATE (SCFM)	TOTAL AIR CONSUMPTION (SCF)
2 OCT 79	1230-1400	90	4,424	551	347.1	31,239
2 OCT 79	1400-1415	15	401	552	188.4	2,826
2 OCT 79	1415-1600	105	5,264	552	353.4	37,107
2 OCT 79	OVERNIGHT	960	2,302	544	17.1	16,416
3 OCT 79	0800-1000	120	5,642	539	339.4	40,728
3 OCT 79	1000-1015	15	281	544	134.0	2,010
3 OCT 79	1015-1200	105	5,074	545	345.0	36,225
3 OCT 79	1200-1230	30	858	547	203.4	6,102
3 OCT 79	1230-1400	90	4,910	549	386.6	34,794
3 OCT 79	1400-1415	15	440	550	207.5	3,113
3 OCT 79	1415-1600	105	5,515	551	370.9	38,945
3 OCT 79	OVERNIGHT	960	2,211	540	16.6	15,936
4 OCT 79	0800-1000	120	6,132	534	372.3	44,676
4 OCT 79	1000-1015	15	447	540	214.7	3,221
4 OCT 79	1015-1200	105	5,555	542	379.8	39,879
4 OCT 79	1200-1230	30	935	544	222.9	6,687
4 OCT 79	1230-1400	90	4,350	545	345.0	31,050
4 OCT 79	1400-1415	15	346	546	164.4	2,466
4 OCT 79	1415-1600	105	4,664	547	315.9	33,169
4 OCT 79	OVERNIGHT	960	2,897	536	21.9	21,024
5 OCT 79	0800-1000	120	5,589	531	341.3	40,956
5 OCT 79	1000-1015	15	399	539	192.0	2,880
5 OCT 79	1015-1200	105	4,929	542	337.0	35,385
8 OCT 79	OVERNIGHT	960	7,283	544	54.3	52,128
9 OCT 79	0800-1000	120	5,200	535	315.1	37,812
9 OCT 79	1000-1015	15	373	534	181.2	2,718
9 OCT 79	1015-1200	105	4,902	535	339.5	35,647
9 OCT 79	1200-1230	30	766	535	185.7	5,571
9 OCT 79	1230-1400	90	3,927	534	317.9	28,611
9 OCT 79	1400-1415	15	395	534	191.9	2,879
9 OCT 79	1415-1600	105	4,617	535	319.8	33,579
9 OCT 79	OVERNIGHT	960	6,863	532	52.3	50,208
10 OCT 79	0800-1000	120	5,040	528	309.5	37,140
10 OCT 79	1000-1015	15	422	529	206.9	3,103
10 OCT 79	1015-1200	105	4,756	532	331.3	34,787
10 OCT 79	1200-1230	30	725	536	175.4	5,262
10 OCT 79	1230-1400	90	2,970	535	240.0	21,600
10 OCT 79	1400-1415	15	394	535	191.0	2,865
10 OCT 79	1415-1600	105	4,287	536	296.4	31,122
10 OCT 79	OVERNIGHT	960	9,796	534	74.3	71,328
11 OCT 79	0800-1000	120	5,484	533	333.6	40,032
11 OCT 79	1000-1015	15	364	535	176.5	2,647
11 OCT 79	1015-1200	105	4,608	539	316.8	33,264
11 OCT 79	1200-1230	30	730	543	174.4	5,232
11 OCT 79	1230-1400	90	3,950	546	312.7	28,143
11 OCT 79	1400-1415	15	355	548	168.0	2,520
11 OCT 79	1415-1600	105	4,352	553	291.6	30,618

Table 2. Work station air consumption rates and metering data

AREA AND WORK STATION	DATE METERED	METER USED	AVERAGE TEMPERATURE (^{o}R)	AVERAGE PRESSURE (PSIA)	PERIOD OF PEAK (SEC)	PEAK USAGE RATE (ACFS)	NON-PEAK USAGE RATE (ACFS)	USAGE DURING PEAK (ACF)	AVERAGE PERIOD OF PEAK (SEC)	AVERAGE USAGE DURING PEAK (SCF)	AVERAGE NON-PEAK USAGE RATE (SCFM)
HARDNESS TESTING, LEAD INSERT, FOILING											
System #1	19 MAR 79	FT-8-8N7.5-GB	536	102.7	4	0.038	0.033	0.150			
System #3	13 MAR 79	FT-8-8N7.5-GB	537	97.7	4	0.034	0.020	0.138			
System #3	13 MAR 79	FT-8-8N7.5-GB	534	100.7	4	0.030	0.025	0.118	4	0.93	10.24
System #3	23 FEB 79	FT-8-8N7.5-GB	535	104.7	5	0.030	0.024	0.150			
BODY LOADING (System #2 only)											
Air Drop #1	19 APR 79	FTM-N10-GJS	533	111.7	4	0.003	0.002	0.012	4	0.086	0.945
Air Drop #2	20 APR 79	FTM-N10-GJS	535	113.2	60	0.005	0.0	0.276	60	2.000	0.0
Air Drop #3	2 MAY 79	FTM-N10-GJS	532	113.2	25	0.005	0.0004	0.127	25	0.96	1.536
Air Disassembly	7 MAY 79	FTM-N10-GJS	542	113.2	315	0.004	0.001	1.300	315	9.60	0.476
Air Drop #5	9 MAY 79	FTM-N10-GJS	539	113.7	3	0.0003	0.0	0.002	3	0.0112	0.0
ASSEMBLY MACHINES											
System #4	12 APR 79	FT-8-8N7.5-GB	535	109.7	15	0.02	0.011	0.35			
System #5	10 APR 79	FT-8-8N7.5-GB	536	110.7	6	0.04	0.017	0.24	11	2.54	4.92
PACKOUT											
Forward Plate Insertion	11 MAY 79	FTM-N10-GJS	538	109.7	4	0.0003	0.0	0.0013	4	0.0094	0.0
Grenade Layer Inserter #7	27 MAR 79	FTM-N10-GJS	536	95.7	3	0.0018	0.001	0.0053	3	0.034	0.450
Grenade Layer Inserter #7	22 MAY 79	FTM-N10-GJS	533	108.7	2	0.0024	0.001	0.0047			
Shim Insertion	25 MAY 79	FTM-N10-GJS	537	107.7	5	0.0011	0.0002	0.0053	5	0.038	0.094
Projectile Caging	28 MAY 79	FTM-N10-GJS	541	109.7	2	0.0013	0.001	0.0025	2	0.018	0.45
Base Plug Torque	4 JUN 79	FTM-N10-GJS	539	110.7	3	0.0014	0.0006	0.0042	3	0.031	0.24
Projectile Weighing	20 JUN 79	FTM-N10-GJS	550	107.7	4	0.0013	0.0002	0.0053	4	0.037	0.089
Projectile Marking	12 JUL 79	FT-8-8N7.5-GB	541	114.7	4	0.0220	0.016	0.0880	4	0.660	7.05
Nose Plug Torque	4 SEP 79	FTM-N10-GJS	536	111.7	18	0.0012	0.0007	0.0212	18	0.160	0.32
Leak Test	1 AUG 79	FTM-N10-GJS	546	113.7	5	0.0028	0.0005	0.0140	5	0.100	0.86
Projectile Transfer	13 JUN 79	FTM-N10-GJS	544	61.7	24	0.0007	0.00004	0.0170	24	0.068	0.01

Table 3. Air compressor output and predicted process consumption

DATE	DAILY CONSUMPTION		ONE-SHIFT CONSUMPTION		PREDICTED PROCESS CONSUMPTION	
	TIME PERIOD (HOURS)	TOTAL AIR CONSUMPTION (SCF)	TIME PERIOD (HOURS)	TOTAL AIR CONSUMPTION (SCF)	TIME PERIOD (HOURS)	TOTAL AIR CONSUMPTION (SCF)
2 OCT 79	19.5	87,588	3.5	71,172	3.5	29,664
3 OCT 79	24	177,852	8	161,916	8	70,308
4 OCT 79	24	182,172	8	161,148	8	63,431
5 OCT 79	4	79,221	4	79,221	4	30,167
8 OCT 79	16	52,128	8	0	8	0
9 OCT 79	24	197,025	8	146,817	8	60,156
10 OCT 79	24	207,207	8	135,879	8	56,648
11 OCT 79	8	142,456	8	142,456	8	57,442
AVERAGES		188,200		151,439		61,948
PERCENT OF DAILY TOTAL		100.0		80.5		32.9

Table 4. Work station air consumption, equivalent energy, and energy cost for varying production levels

AREA AND WORK STATION	ONE 8-HOUR SHIFT - 750 ROUNDS			ONE 8-HOUR SHIFT - 960 ROUNDS			ONE 12-HOUR SHIFT - 1,440 ROUNDS			THREE 8-HOUR SHIFTS - 2,250 ROUNDS		
	AIR CONSUMPTION (SCF)	EQUIVALENT ENERGY (KWH)	ENERGY COST ($)	AIR CONSUMPTION (SCF)	EQUIVALENT ENERGY (KWH)	ENERGY COST ($)	AIR CONSUMPTION (SCF)	EQUIVALENT ENERGY (KWH)	ENERGY COST ($)	AIR CONSUMPTION (SCF)	EQUIVALENT ENERGY (KWH)	ENERGY COST ($)
HARDNESS TESTING, LEAD INSERT, FOILING												
Total For Area	11,463 (2 Systems)	68	2.72	11,920 (2 Systems)	71	2.83	17,880 (3 Systems)	106	4.24	34,298 (2 Systems)	203	8.13
BODY LOADING												
Air Drop #1	1,160	7	0.27	1,231	7	0.29	1,847	11	0.44	3,480	21	0.82
Air Drop #2	1,468	9	0.35	1,876	11	0.44	2,814	17	0.67	4,404	26	1.04
Air Drop #3	2,038	12	0.48	2,196	13	0.52	3,294	20	0.78	6,114	36	1.45
Air Disassembly	1,451	9	0.34	1,766	11	0.42	2,648	16	0.63	4,353	26	1.03
Air Drop #5	164	1	0.04	210	1	0.05	315	2	0.07	492	3	0.12
Total For Area	6,281 (2 Systems)	37	1.49	7,279 (2 Systems)	43	1.73	10,918 (3 Systems)	65	2.59	18,843 (2 Systems	112	4.47
ASSEMBLY MACHINES												
Total For Area	38,549 (8 Systems)	229	9.14	44,053 (8 Systems)	261	10.44	61,356 (10 Systems)	364	14.54	115,646 (8 Systems)	685	27.41
PACKOUT												
Forward Plate Insertion	7	0	0.00	9	0	0.00	14	0	0.00	21	0	0.00
Grenade Layer Inserters (11)	2,471	15	0.59	2,497	15	0.59	3,747	22	0.89	7,412	44	1.76
Shim Insertion	68	1	0.02	74	1	0.02	111	1	0.03	203	1	0.05
Projectile Gaging	218	1	0.05	219	1	0.05	328	2	0.08	655	4	0.16
Base Plug Torque	130	1	0.03	133	1	0.03	200	1	0.05	389	2	0.09
Projectile Weighing	66	1	0.02	73	1	0.02	109	1	0.03	198	1	0.05
Projectile Marking	3,527	21	0.84	3,566	21	0.85	5,350	32	1.27	10,580	63	2.51
Nose Plug Torque	202	1	0.05	215	1	0.05	323	2	0.08	605	4	0.14
Leak Test	434	3	0.10	440	3	0.10	660	4	0.16	1,302	8	0.31
Projectile Transfer	106	1	0.03	133	1	0.03	199	1	0.05	317	2	0.08
Total For Area	7,227	43	1.71	7,359	44	1.74	11,039	66	2.62	21,681	129	5.14
TOTAL OF ALL PROCESSES	63,490	376	15.05	70,610	418	16.73	101,193	600	23.98	190,469	1,129	45.14

Table 5. Cumulative production totals* - 2 October 79 through 5 October 79

AREA AND WORK STATION	Items produced											
	2 Oct 79		3 Oct 79				4 Oct 79				5 Oct 79	
	Time interval											
	1200-1400	1400-1600	0800-1000	1000-1200	1200-1400	1400-1600	0800-1000	1000-1200	1200-1400	1400-1600	0800-1000	1000-1200
HARDNESS TESTING, LEAD INSERT, FOILING												
System #1	12,288	18,432	9,216	24,576	- - - -	46,080	9,216	18,432	30,720	43,008	9,216	15,360
System #3	0	6,144	0	12,208	- - - -	24,576	6,144	9,216	9,216	12,288	9,216	15,360
BODYLOADING												
System #1	6,912	16,128	6,912	18,432	25,344	34,560	6,912	13,824	23,040	29,952	9,216	16,128
System #2	9,216	18,432	6,912	16,128	23,040	34,560	9,216	18,432	18,432	25,344	6,912	13,824
ASSEMBLY MACHINES												
System #1	771	3,393	2,608	5,071	7,450	10,020	2,127	4,617	6,522	7,320	2,051	4,650
System #2	1,720	4,410	3,199	5,950	8,438	11,140	3,169	6,010	8,636	10,840	0	0
System #3	2,553	4,715	2,860	4,068	5,371	7,260	2,546	5,272	7,315	9,120	2,308	5,048
System #4	0	0	2,552	4,510	6,504	8,420	2,740	4,970	6,334	8,130	2,750	5,450
System #5	1,863	4,463	2,532	4,128	6,284	8,630	0	0	0	0	1,805	3,537
System #6	1,861	3,350	2,389	4,650	6,673	9,140	2,260	4,502	6,473	8,310	2,365	4,860
System #7	1,377	3,087	1,122	2,485	4,403	5,962	949	3,371	5,129	5,435	0	0
System #8	1,860	4,356	2,641	5,094	7,335	9,840	2,914	5,591	7,974	10,129	2,412	5,230
System #9	1,794	4,173	2,276	5,835	6,704	9,532	2,262	4,939	7,310	9,215	1,642	3,436
System #10	534	2,606	0	0	0	0	0	0	0	0	0	0
PACKOUT												
Entire Line	176	368	232	368	536	752	216	384	520	744	196	420

*Packout quantities are for completed rounds; other quantities are for grenades.

Table 6. Cumulative production totals* - 9 October 79 through 11 October 79

AREA AND WORK STATION	Items produced											
	9 Oct 79				10 Oct 79				11 Oct 79			
	Time interval											
	0800-1000	1000-1200	1200-1400	1400-1600	0800-1000	1000-1200	1200-1400	1400-160C	0800-1000	1000-1200	1200-1400	1400-1600
HARDNESS TESTING, LEAD INSERT, FOILING												
System #1	9,216	21,504	30,720	52,224	18,432	33,792	43,008	55,296	9,216	24,576	33,792	49,152
System #3	9,216	15,350	18,432	33,792	6,144	12,288	12,288	21,504	6,144	6,144	6,144	6,144
BODYLOADING												
System #1	4,608	13,824	20,736	25,344	6,912	16,128	23,040	35,180	9,216	16,128	25,344	34,560
System #2	3,968	13,184	20,096	27,008	6,912	18,432	25,344	34,560	11,520	20,736	32,256	41,472
ASSEMBLY MACHINES												
System #1	2,461	4,848	7,266	9,835	2,681	4,547	5,395	6,314	901	2,357	4,058	6,340
System #2	3,098	5,739	8,350	11,120	2,547	4,860	6,083	7,620	0	0	0	0
System #3	2,526	4,690	6,350	6,519	2,050	4,245	4,889	7,514	2,550	5,187	7,295	9,720
System #4	557	557	557	557	2,135	3,709	4,326	6,720	410	410	410	1,980
System #5	0	0	0	0	0	0	0	0	1,236	1,867	3,415	5,430
System #6	2,690	5,146	7,210	9,516	2,131	4,108	4,966	7,040	2,725	4,415	5,639	6,420
System #7	627	2,893	4,562	6,832	0	0	0	0	1,296	3,810	5,782	8,240
System #8	3,154	5,708	7,315	10,032	2,861	4,257	4,913	6,440	2,848	5,010	6,905	9,560
System #9	1,930	4,138	6,371	9,023	2,305	4,190	5,250	7,620	2,551	4,682	6,859	9,320
System #10	0	0	0	0	0	0	0	0	0	0	0	0
PACKOUT												
Entire Line	176	400	472	700	208	408	584	760	168	408	592	776

*Packout quantities are for completed rounds; other quantities are for grenades.

Table 7. Process related electrical demand - grenade processing

AREA AND WORK STATION	AC VOLTAGE	PHASE	KW	KVAR	KVA	PF	OPERATING COST/HR AT $.04/KWH	HP	NAMEPLATE AMPS	AMMETER AMPS
HARDNESS TESTING										
#1 Hentschel	117	1	.527		.527		.021	* 1/3	5.3	4.5
#2 "	117	1	.527		.527		.021	* 1/3	5.3	4.5
#3 "	117	1	.538		.538		.022	* 1/3	5.3	4.6
#4 " (Adapters)	117	1	.85		.85		.034	* 1/2	8.6	7.3
LEAD & FOIL INSERTION										
#1 L&F	208	3	1.27	.89	1.55	.82	.051	* 1 5/6	8.1	4.3
#2 "	208	3	1.27	.89	1.55	.82	.051	* 1 5/6	8.1	4.3
#3 "	208	3	1.27	.89	1.55	.82	.051	* 1 5/6	8.1	4.3
Vacuum Pump	480	3	4.3	3.2	5.4	.8	.172	5	6.9	6.5
BODY LOADING										
B.L. #1 System	480	3	24	40	46.2	.52	.96	* 68 1/3	96.9	55
B.L. #2 System	480	3	22	37	43.1	.51	.88	* 68 1/3	96.9	50
B.L. #3 System	480	3	20	30	36.4	.55	.80	* 68 2/3	97.4	44
#1 Sola Instrument Power	120	1	.84		.84		.034	3,000 VA		7
#2 " " "	120	1	.85		.85		.034	3,000 VA		7
#3 " " "	120	1	.85		.85		.034	3,000 VA		7
Powder Conveyor	480	3	8	17.6	20	.40	.32	* 25 1/4	36 3/4	23
ASSEMBLY MACHINES										
# 1 Assembly Machine	480	3	3.6	7.2	8	.45	.144	* 9	15	10
# 2 " "	480	3	4	7.2	8.33	.48	.160	* 9	15	10.5
# 3 " "	480	3	3.2	8	8.65	.37	.128	* 9	15	10.5
# 4 " "	480	3	4	7.2	8.33	.48	.160	* 9	15	10.5
# 5 " "	480	3	4	8	8.65	.45	.160	* 9	15	10.8
# 6 " "	480	3	4	7.2	8.33	.48	.160	* 9	15	11
# 7 " "	480	3	4	7.2	8.33	.48	.160	* 9	15	10.5
# 8 " "	480	3	4	6.8	7.84	.51	.160	* 9	15	9
# 9 " "	480	3	4	7.2	8.33	.48	.160	* 9	15	10.5
#10 " "	480	3	4	7.2	8.33	.48	.160	* 9	15	11
# 1 Sola Instrument Power	120	1	.03		.03		.001	*500 VA		.25
# 2 " " "	120	1	.03		.03		.001	*500 VA		.25
# 3 " " "	120	1	.03		.03		.001	*500 VA		.25
# 4 " " "	120	1	.03		.03		.001	*500 VA		.25
# 5 " " "	120	1	.03		.03		.001	*500 VA		.25
# 6 " " "	120	1	.03		.03		.001	*500 VA		.25
# 7 " " "	120	1	.03		.03		.001	*500 VA		.25
# 8 " " "	120	1	.03		.03		.001	*500 VA		.25
# 9 " " "	120	1	.03		.03		.001	*500 VA		.25
#10 " " "	120	1	.03		.03		.001	*500 VA		.25

*DENOTES SUM OF ALL MOTORS IN SYSTEM

Table 8. Process related electrical demand - packout and air compressors

AREA AND WORK STATION		AC VOLTAGE	PHASE	KW	KVAR	KVA	PF	OPERATING COST/HR AT $.04/KWH	HP	NAMEPLATE AMPS	AMMETER AMPS
PACKOUT											
#1 Conveyor System (East)		480	3	5.6	13.2	14	.40	.224	*20	26	18
#2 Conveyor System (West)		480	3	2.4	4	4.7	.51	.096	*10	13	5.5
Projectile Placing Station		208	3	5	6	7.7	.65	.200	*11	34.6	21.4
Forward Plate Insertion		480	3	2	2.4	3.1	.65	.080	5	6.5	3.7
Grenade Layer Inserter 3-1		480	3	2	2.4	3.1	.65	.080	5	6.5	4
GLI 3-2		480	3	2	2.4	3.1	.65	.080	5	6.5	3.5
GLI 3-3		480	3	2	2	2.86	.70	.080	5	6.5	3.2
GLI 3-4		480	3	1.6	2.4	2.9	.55	.064	5	6.5	3.3
GLI 3-5		480	3	1.6	2	2.58	.62	.064	5	6.5	3.2
GLI 3-6		480	3	2.4	2.4	3.43	.70	.096	5	6.5	3.8
GLI 3-7		480	3	1.6	2.4	2.9	.55	.064	5	6.5	3.4
GLI 3-8		480	3	2.4	2.4	3.43	.70	.096	5	6.5	4
GLI 3-9		480	3	2	2.4	3.1	.65	.080	5	6.5	3.5
GLI 3-10		480	3	1.6	2.4	2.91	.55	.064	5	6.5	3.2
GLI 3-11		480	3	2.4	2.8	3.7	.65	.096	5	7.1	4.4
GLI 3-12		480	3	2.4	2.4	3.43	.70	.096	5	6.5	3.8
GLI 3-13		480	3	2.4	2.4	3.43	.70	.096	5	6.5	3.9
GLI 4		480	3	1.6	2.4	2.9	.55	.064	5	7.1	3.3
Shim Insertion & Gage		480	3	1.6	2.4	2.9	.55	.064	5	7.1	3.5
Base Plug Torque		480	3	4.8	8	9.2	.52	.192	15	20	11.1
Projectile Weigh Station		480	3	1.6	5.6	5.9	.27	.064	10	13.5	7.5
M483 Marking Station		480	3	1.6	5.6	5.9	.27	.064	10	13.5	7.5
Nose Plug Torque		480	3	1.6	5.6	5.9	.27	.064	10	13.5	7.5
Leak Test		480	3	1.6	5.6	5.9	.27	.064	10	13.5	7.1
509 Transfer System		480	3	8	12.8	14.6	.55	.320	*21½	28.8	18
Sola Instrument Power		120	1	.324		.324		.013	1000VA		2.7
Detorque		480	3	2	8.4	8.7	.23	.080	15	20	10.5
315 Compressor House**	U	480	3	56	68	87.5	.64	2.24	125	156	100
	L			98	84	125.6	.78	3.92			150
328 Compressor House**	U	480	3	28	36	45.2	.62	1.12	150	192	55
	L			104	52	119.5	.87	4.16			143
Refrigerated Air Dryer		480	3	22.4	17.6	28	.80	.90	11	27	

* Denotes sum of all motors in the system
** U - Nonproduction period - Low Level Loading (unloaded)
L - Production period - High Level Loading (loaded)

Table 9. Monthly 300 Area Production line electrical demand

MONTH	ELECTRICAL DEMAND (KWH)
JUL 79	128,400
AUG 79	141,600
SEP 79	124,200
OCT 79	118,200
NOV 79	99,600
DEC 79	107,400
WORKING DAYS	125
AVERAGE DAILY DEMAND	5,755

TABLE 9

Table 10. Total energy demand and cost by area for varying production levels

AREA	ONE 8-HOUR SHIFT 750 ROUNDS		ONE 8-HOUR SHIFT 960 ROUNDS		ONE 12-HOUR SHIFT 1,440 ROUNDS		THREE 8-HOUR SHIFTS 2,250 ROUNDS	
	TOTAL ENERGY USED (KWH)	TOTAL ENERGY COST ($)	TOTAL ENERGY USED (KWH)	TOTAL ENERGY COST ($)	TOTAL ENERGY USED (KWH)	TOTAL ENERGY COST ($)	TOTAL ENERGY USED (KWH)	TOTAL ENERGY COST ($)
HARDNESS TESTING, LEAD INSERT, FOILING	138	5.53	141	5.64	191	7.62	415	16.59
BODY LOADING	467	18.67	473	18.91	677	27.09	1,400	56.01
ASSEMBLY MACHINES	479	19.14	511	20.44	676	27.04	1,436	57.42
PACKOUT	539	21.55	540	21.58	809	32.38	1,616	64.65
TOTALS	1,622	64.89	1,664	66.57	2,353	94.13	4,867	194.67

Table 11. Breakdown of motors in each system having multiple motors

WORK STATION	VOLTAGE	PHASE	HP	NAMEPLATE AMPS
HARDNESS TEST AREA				
Hardness Tester (Body)	120	1	1/6	3.3
	120	1	1/6	2
Hardness Tester (Adapters)	120	1	1/6	3.3
	120	1	1/6	2
	120	1	1/6	3.3
Lead & Foil Insertion	208	3	1/2	2.2
	208	3	1/3	1.5
	208	3	1/2	2.2
	208	3	1/2	2.2
ONE BODY LOADER	480	3	1/2	1.1
	480	3	1/3	.75
	480	3	1/2	1.1
	480	3	1/3	.6
	480	3	15	20
	480	3	15	20
	480	3	1/3	.45
	480	3	1/2	1.1
	480	3	1/3	.75
	480	3	1/3	.6
	480	3	1/3	.6
	480	3	1/3	.75
	480	3	1/4	.57
	480	3	1/4	1.0
	480	3	1/3	.75
	480	3	1/2	1.1
	480	3	1/3	.75
	480	3	1/2	1.1
	480	3	1/3	.6
(In BL #3 only)	480	3	1/3	.75
(Vacuum System)	480	3	5	6.9
(Vacuum System)	480	3	5	6.9
(Chillers)	480	3	22	29.4
POWDER CONVEYOR SYSTEM	480	3	5	7
	480	3	3/4	1.25
	480	3	3/4	1.25
	480	3	3/4	1.25
	480	3	3/4	1.25
	480	3	3/4	1.25
	480	3	3/4	1.25
	480	3	5	7
	480	3	5	7
	480	3	5	7
	480	3	3/4	1.25
ONE ASSEMBLY MACHINE	480	3	1/4	.57
	480	3	1/3	.75
	480	3	1/2	1.1
	480	3	1/3	.75
	480	3	1/2	1.1
	480	3	2	3.7
	480	3	5	7.0
PACKOUT				
East Conveyor	480	3	5	6.5
	480	3	5	6.5
	480	3	5	6.5
	480	3	5	6.5
West Conveyor	480	3	5	6.5
	480	3	5	6.5
509 Transfer System	480	3	5	6.5
	480	3	2	3.0
	480	3	10	13
	480	3	10	13
	480	3	3/4	1.4
	480	3	3/4	1.4
Projectile Placing Station	208	3	1/2	4
	208	3	1/2	4
	208	3	10	26.6

Table 12. Energy saving opportunities

Operation	Opportunity	Cost ($) 1 shift/day	Cost ($) 3 shifts/day	Savings ($/year) 1 shift/day	Savings ($/year) 3 shifts/day	Payback (years) 1 shift/day	Payback (years) 3 shifts/day
All	Revise general maintenance and operating procedures in accordance with cost effective energy conservation practices.	Negligible	Negligible	850	2,250	-	-
Body Loading	Install power factor correction capacitors on 15 HP hydraulic motors	1,000	1,500	530	1,590	1.9	0.9
Assembly Machine	Install power factor correction capacitors on 5 HP drive motors	1,040	1,300	400	1,500	2,7	0.9
Packout	Install power factor correction capacitor on Conveyor System #1 (East).	300	300	125	375	2.4	0.8
	Install power factor correction capacitor on Conveyor System #2 (West)	150	150	85	250	1.8	0.6
	Consolidate hydraulic pumps and then add power factor correction capacitors to the remaining motors in the Forward Plate Insertion, Grenade Layer Insertion, Shim Insertion and Gaging sub-operations	1,040*	1,040*	410	1,225	2.5	0.8
	Install power factor correction capacitor on Base Plug Torque machine	250	250	135	400	1.9	0.6
	Consolidate hydraulic pump system from two pumps and then add power factor correction capacitor to the remaining pump in the Projectile Weigh and M483 Marking Stations	150*	150*	105	310	1.4	0.5
	Consolidate hydraulic pump system from two pumps to one and then add power correction capacitor to the remaining pump in the Nose Plug Torque and Leak Test stations	150*	150*	105	310	1.4	0.5
	Install power factor correction capacitor on the 125 HP compressor motor in Building 315	400	400	750	1,125	0.5	0.4
All	Select most cost-effective control logic system for each machine operation	Requires additional investigation to establish precise cost effectiveness.					
		TOTAL SAVINGS		3,495	9,635		

* Hydraulic system modification cost has not been included in this cost figure because it is dependent upon final design which has not yet been established. It's cost, however, is expected to be off-set by additional savings over and above those listed.

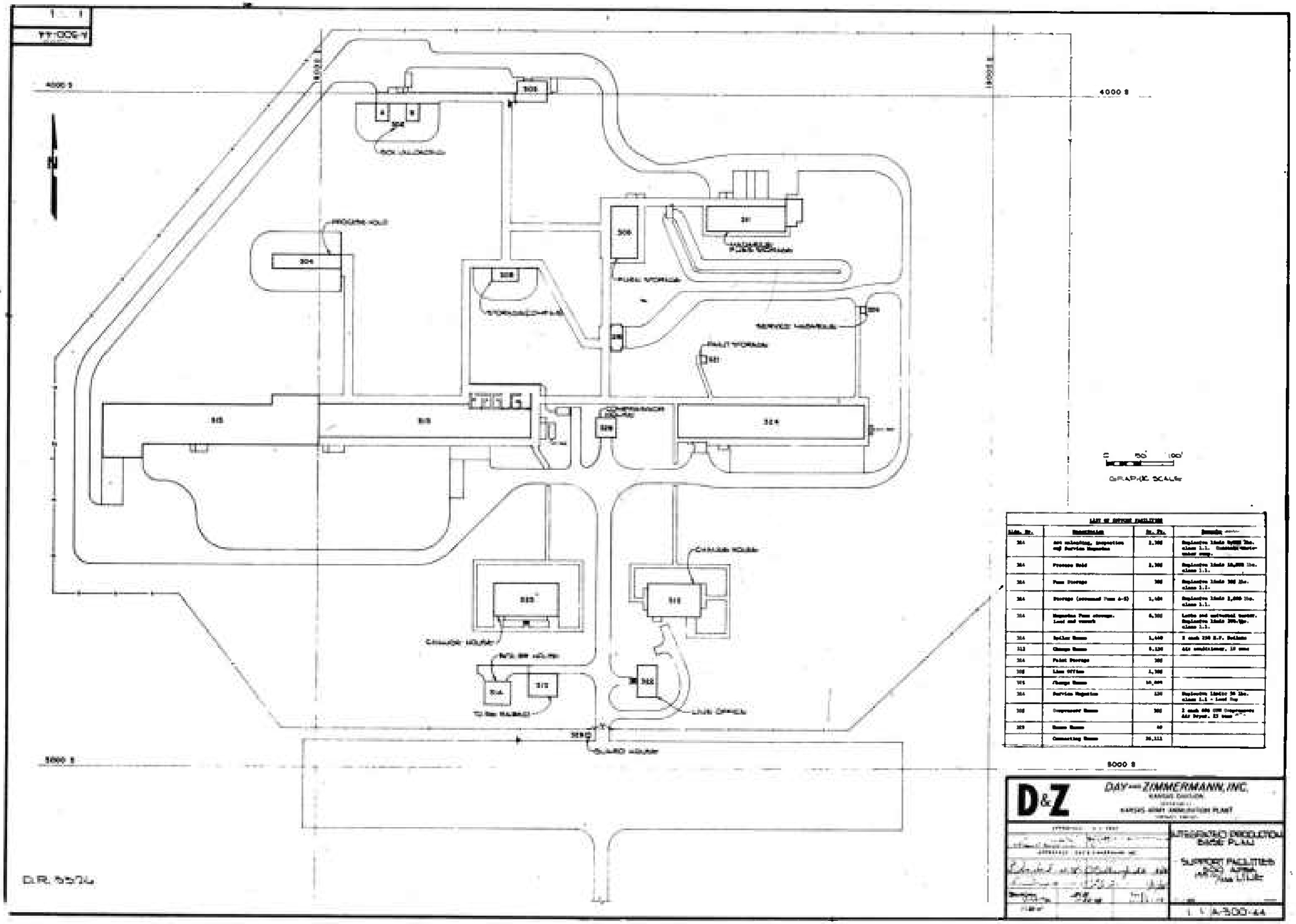


Figure 1. 300 Area production line

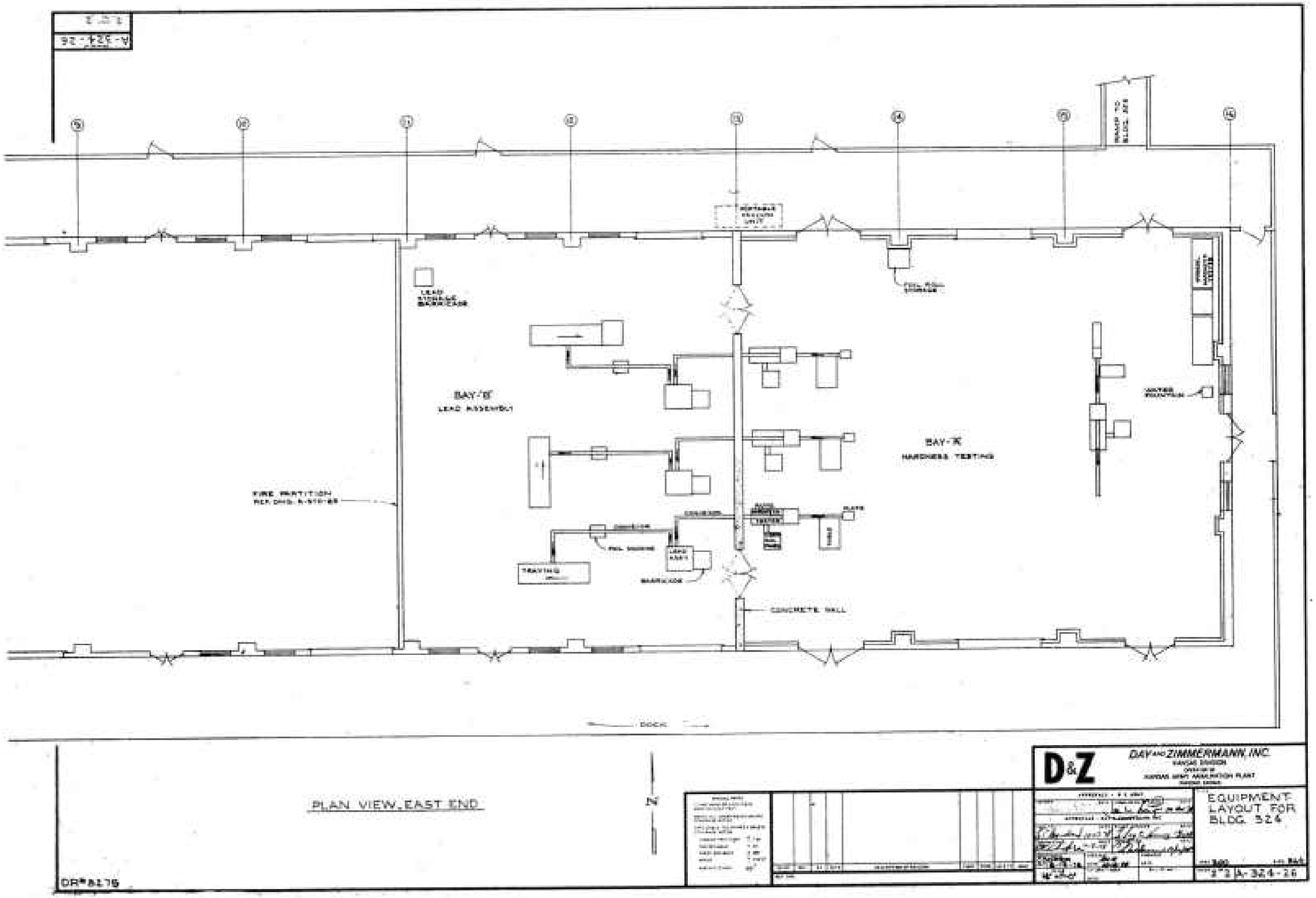


Figure 2. Equipment layout - Building 324

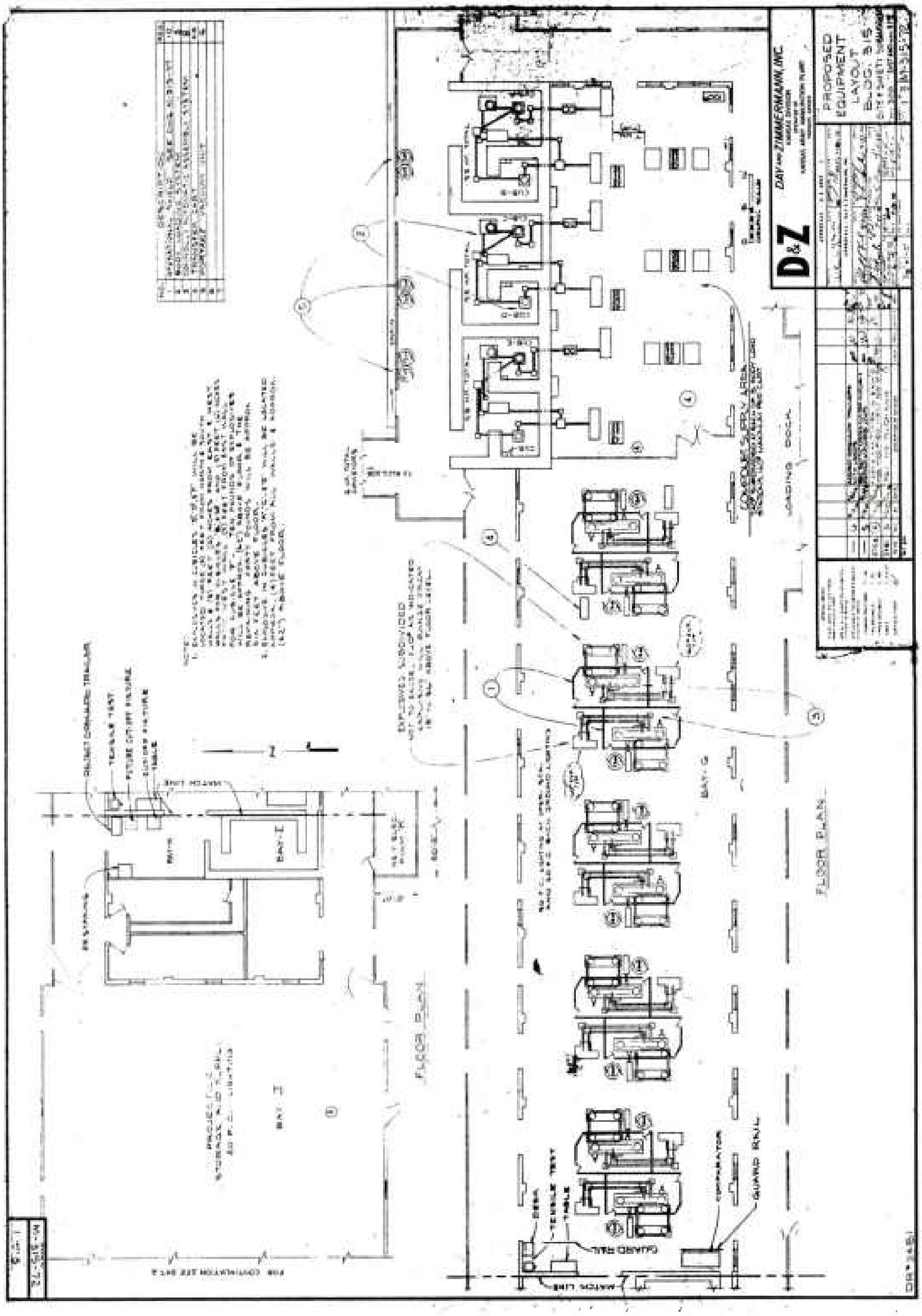


Figure 3. Equipment layout - Building 315 (east)

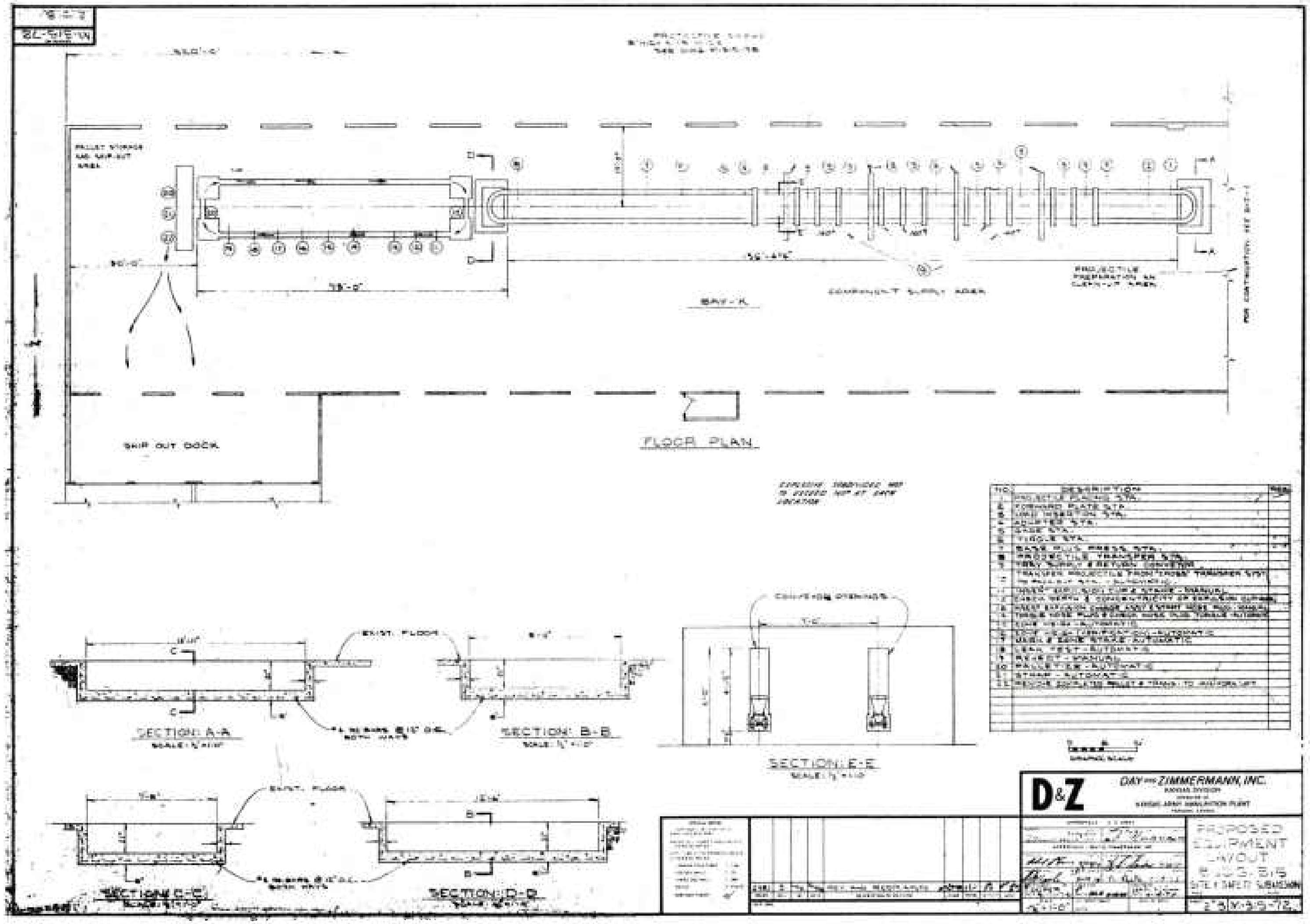


Figure 4. Equipment layout - Building 315 (west)

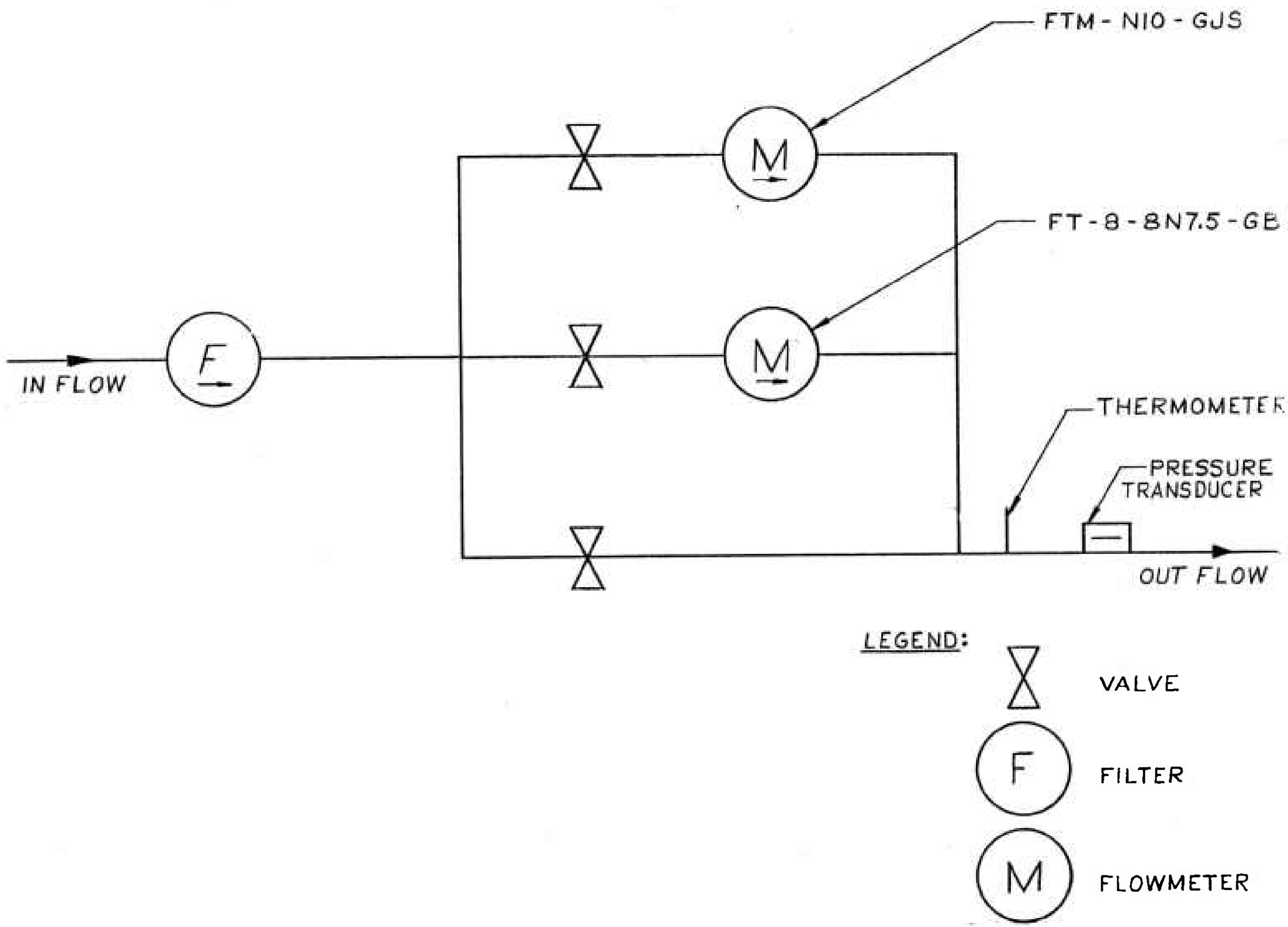


Figure 5. Air metering manifold system

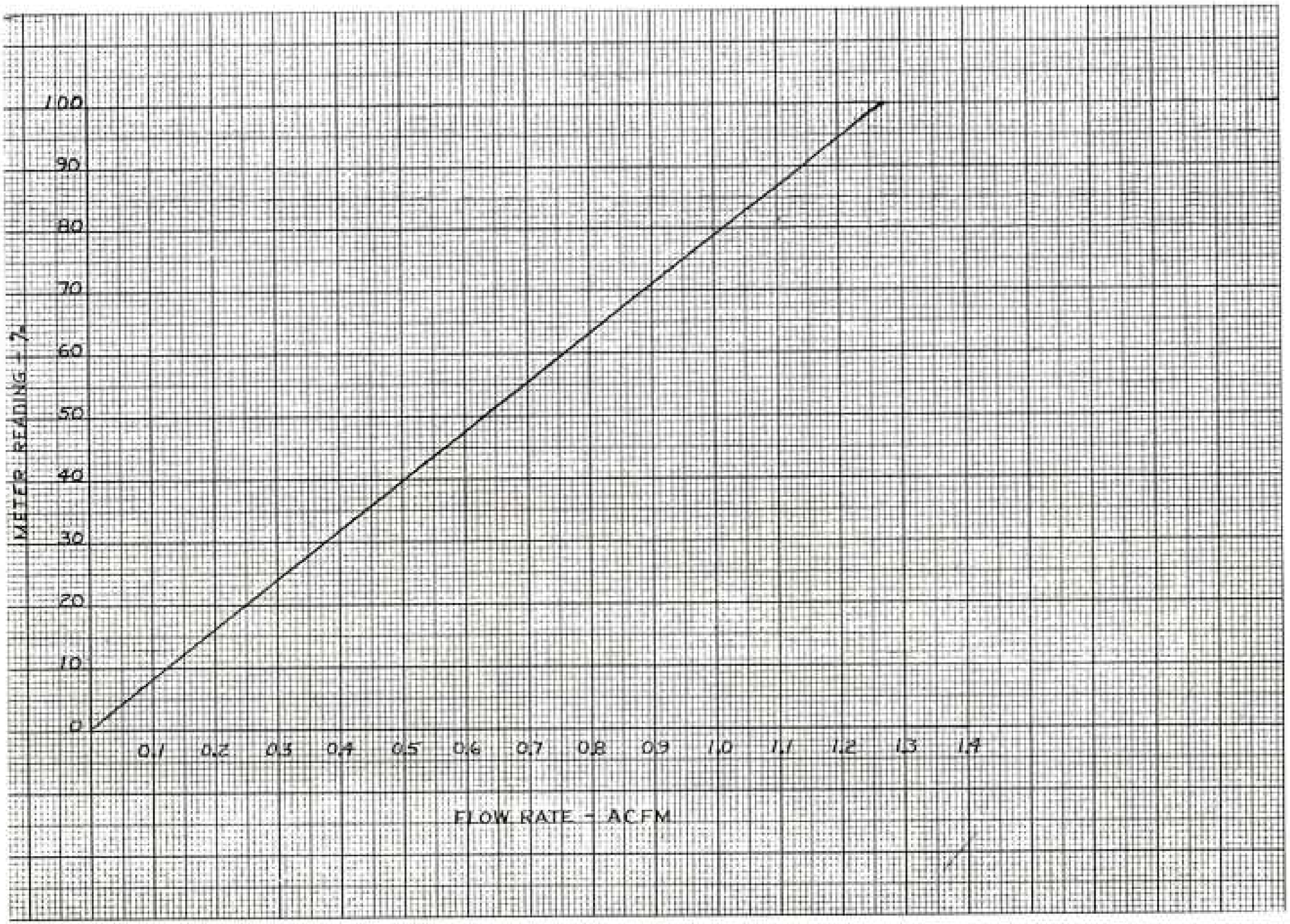


Figure 6. FTM-N10-GJS - Meter reading vs. flow rate

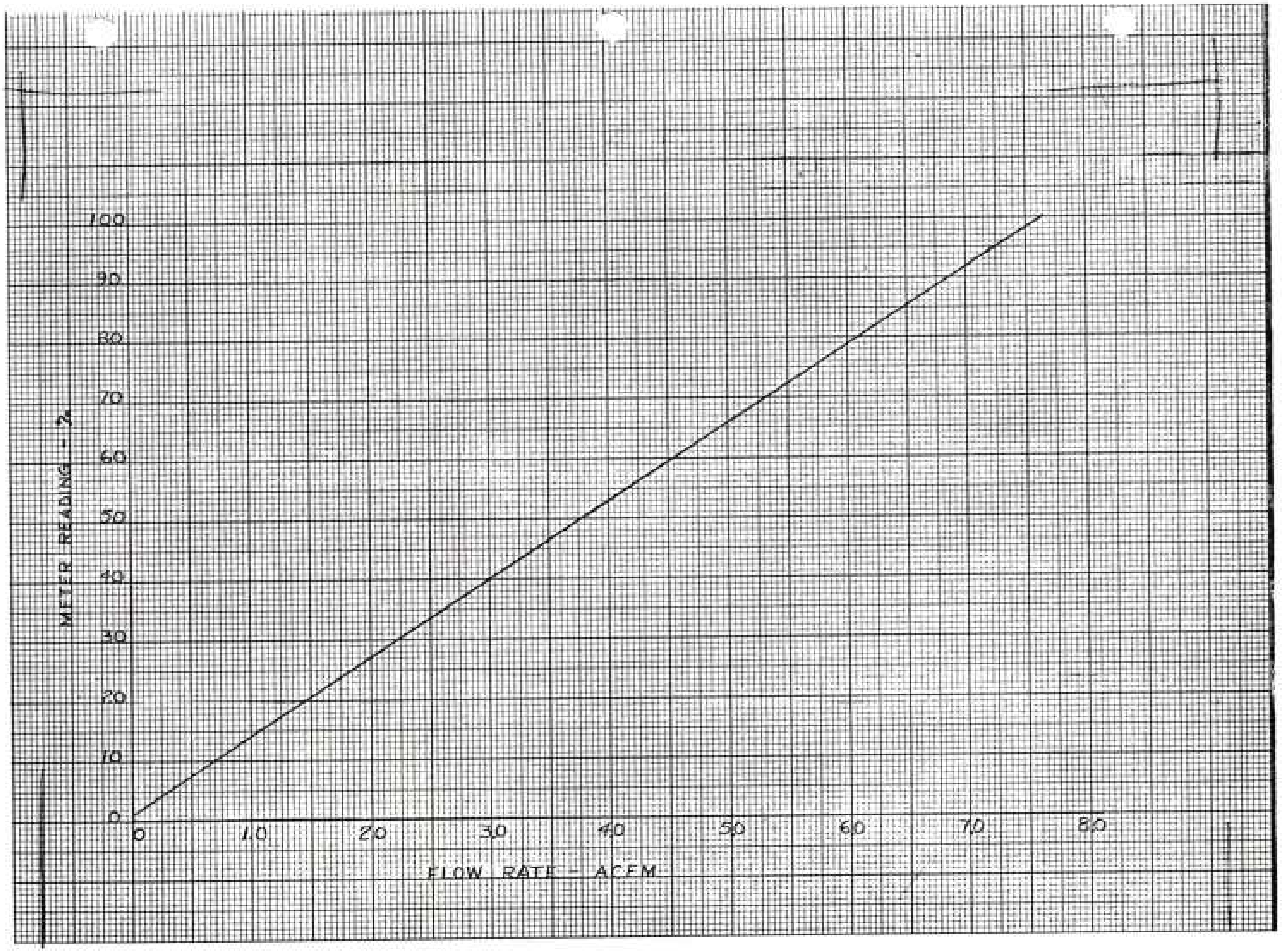
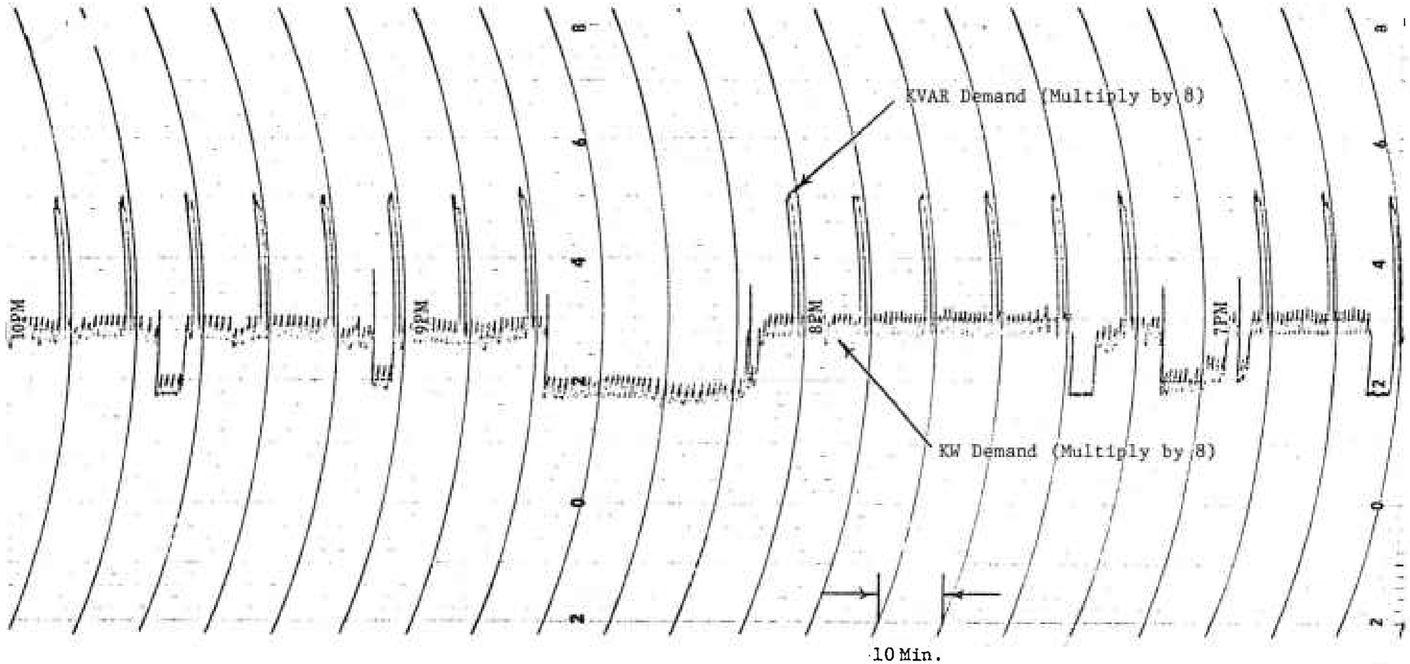


Figure 7. FT-8-8N7.5-GB - Meter reading vs. flow rate



Top Scale = Air use (refer to figures 6 & 7)
Bottom Scale = Air gage pressure, psig

Figure 8. Typical process air consumption stripchart

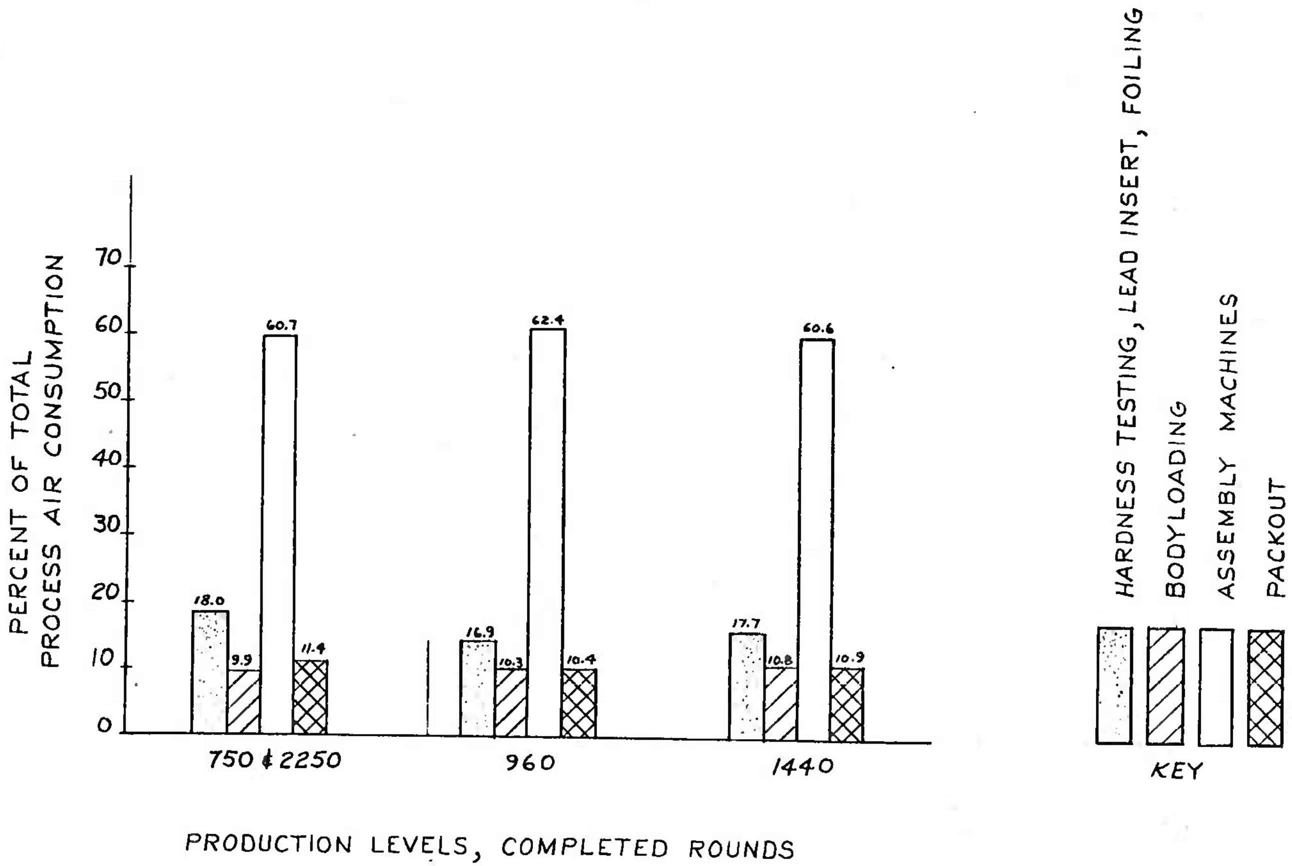


Figure 9. Air consumption by area for varying production levels

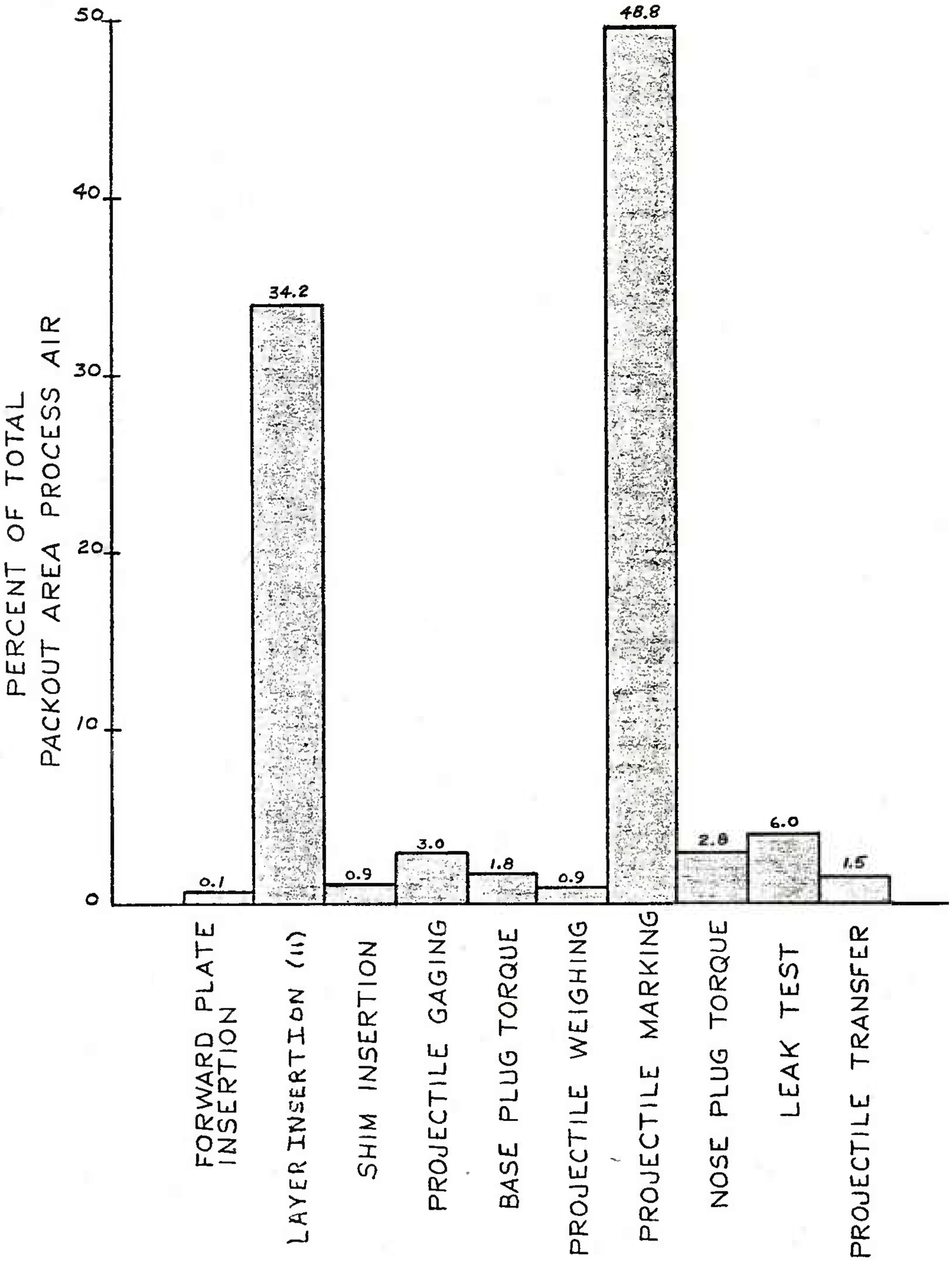


Figure 10. Air consumption by packout area process for varying production levels

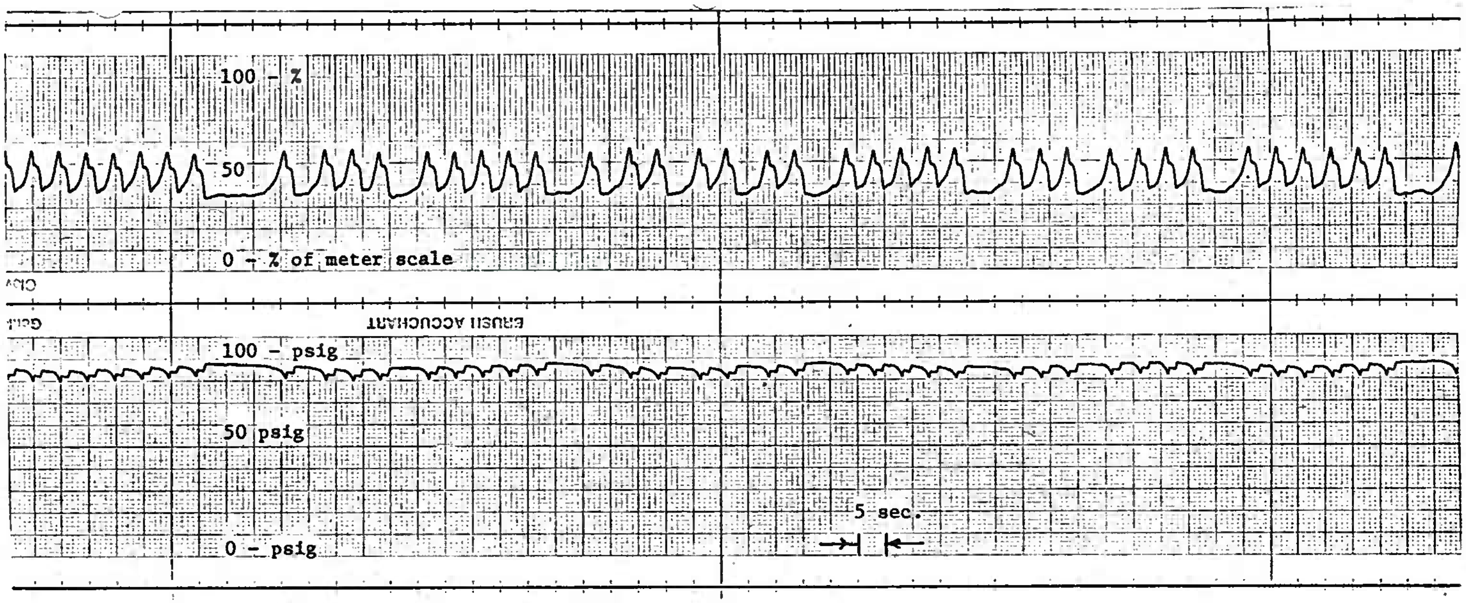


Figure 11. Typical electrical demand stripchart

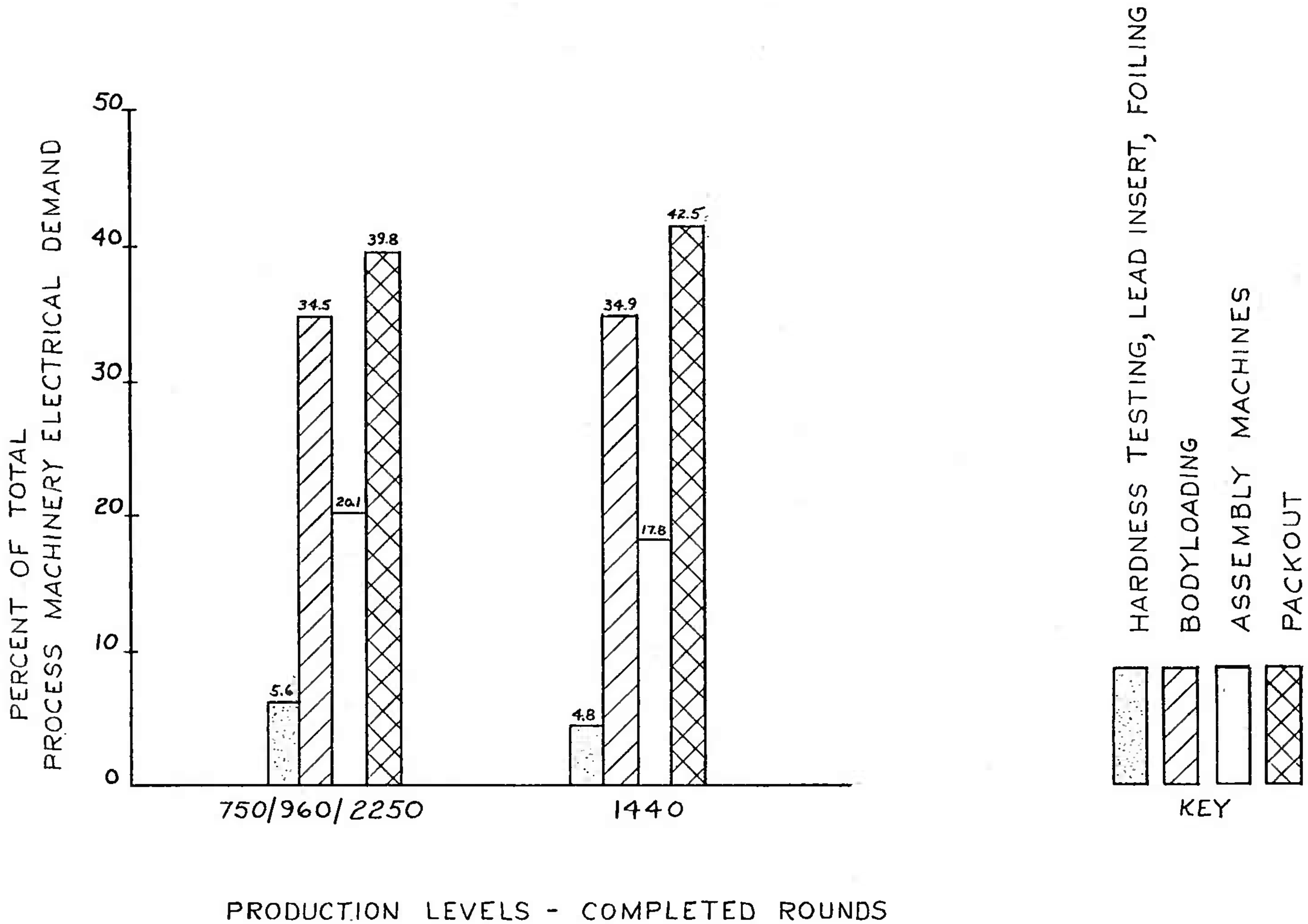


Figure 12. Total process machinery electrical demand by area for varying production levels

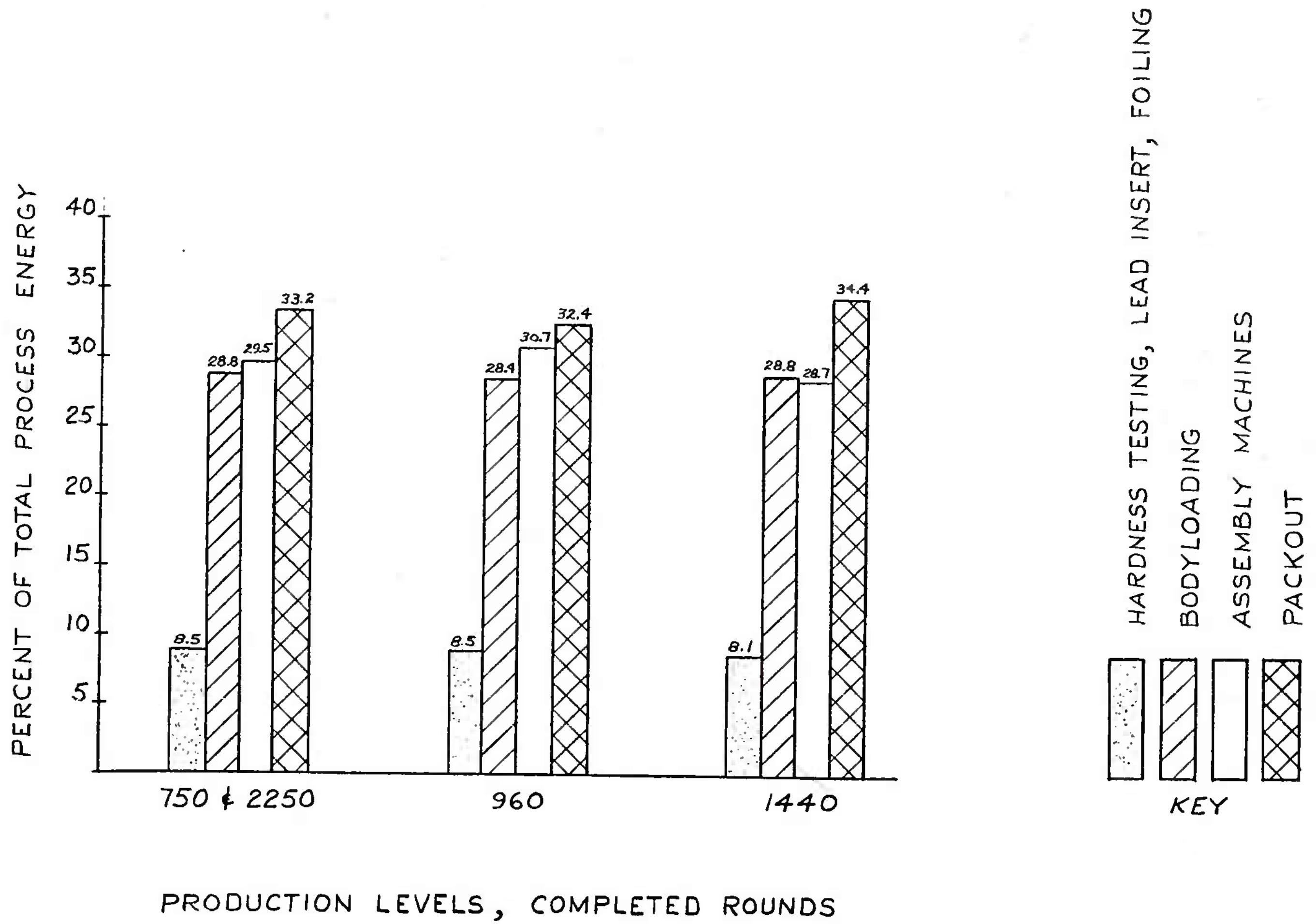


Figure 13. Total energy consumption by area for varying production levels

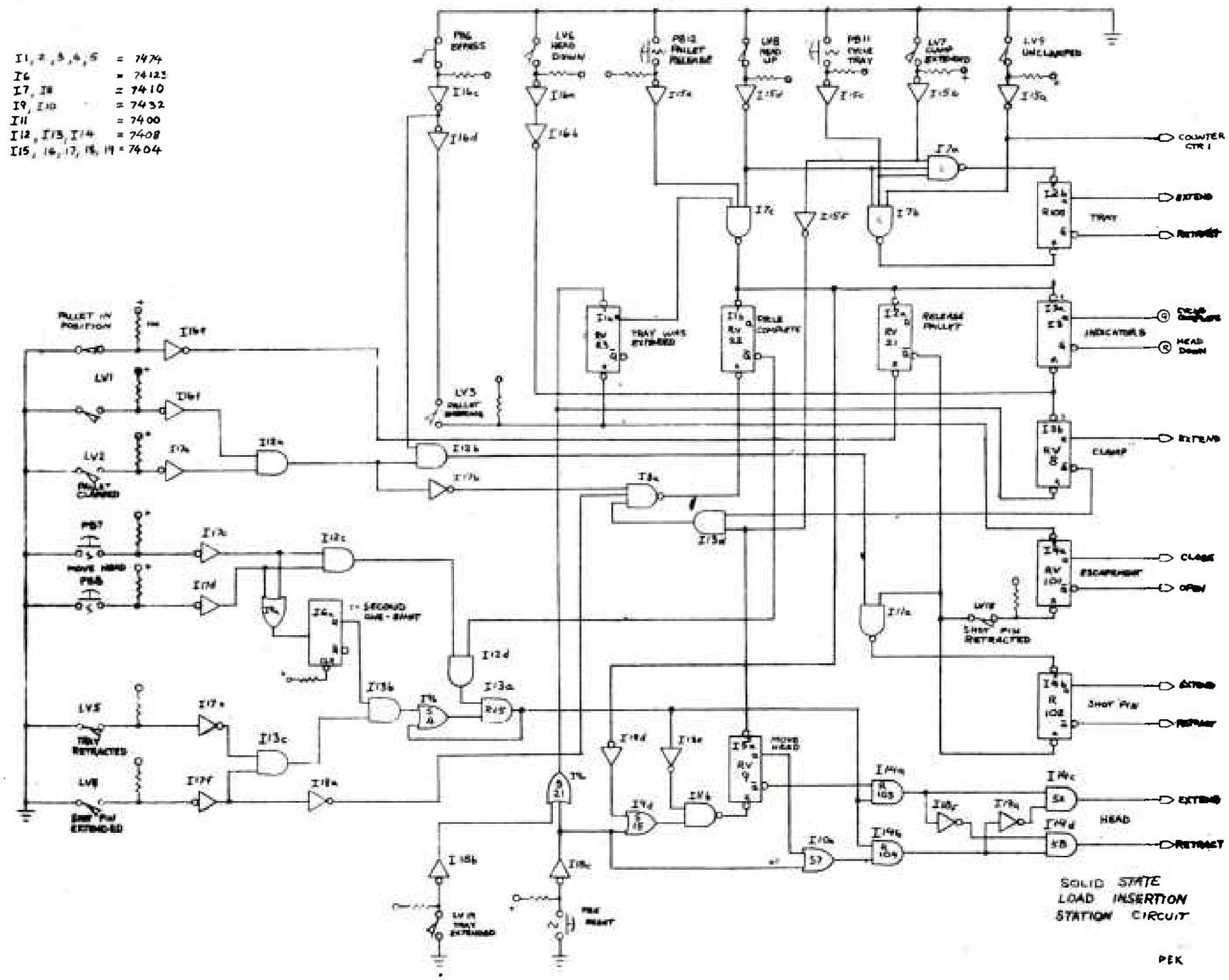


Figure 14. Solid state load insertion station circuit

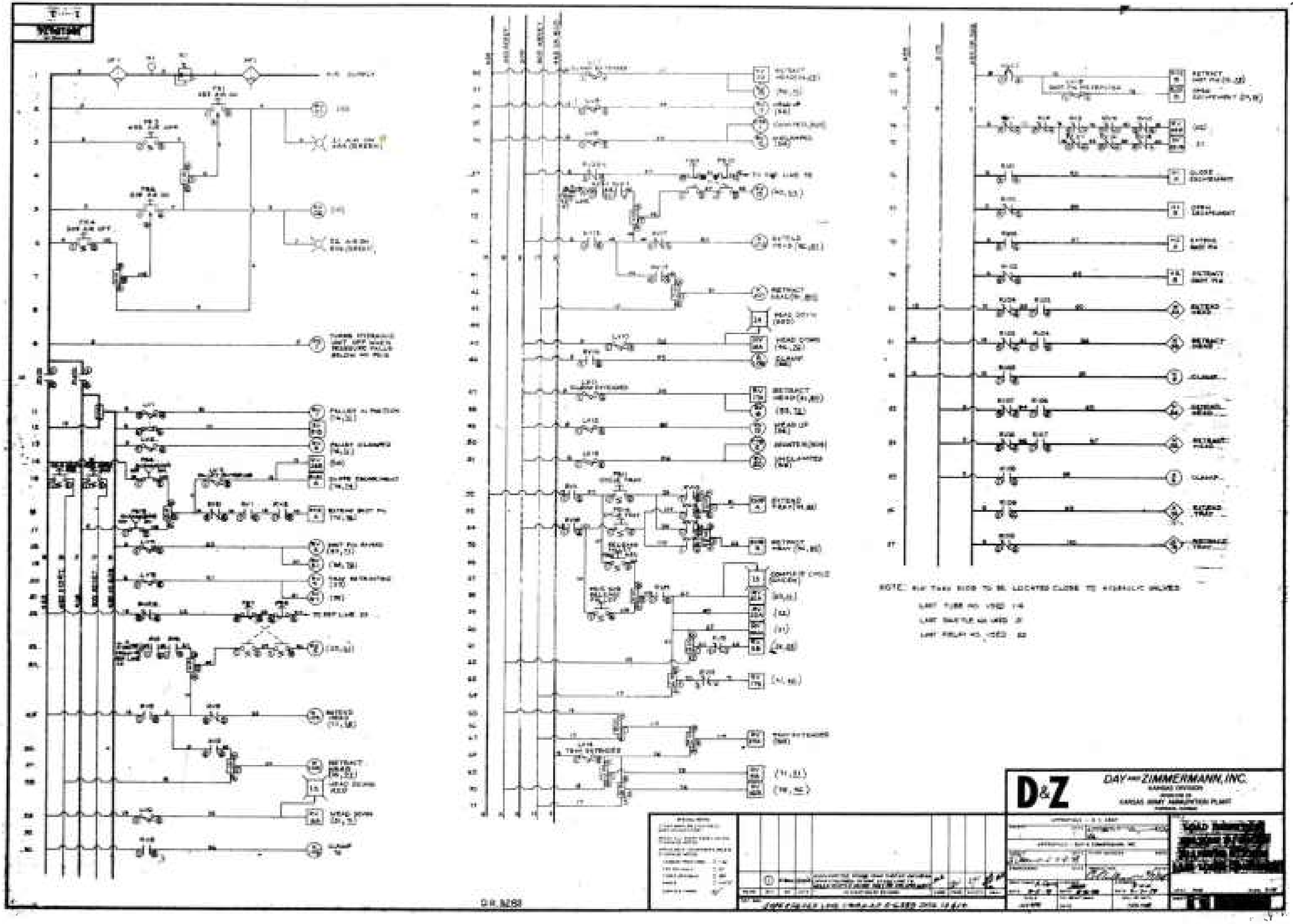


Figure 15. Load insertion station air logic controls

APPENDIX A

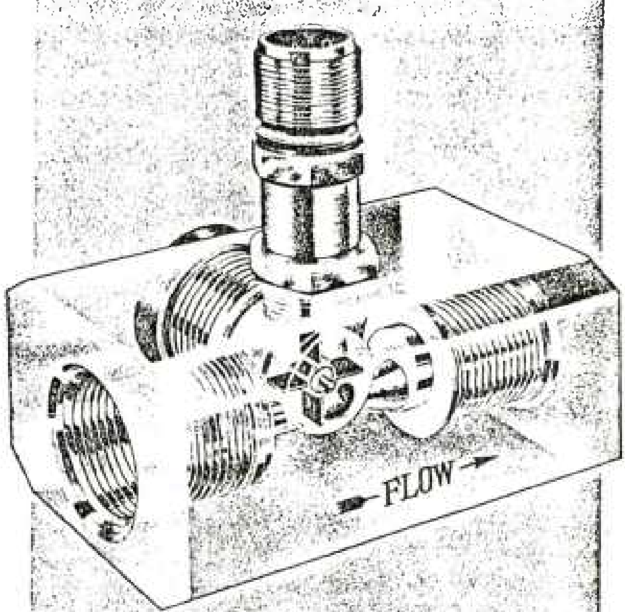
OMNIFLO TURBINE FLOW TRANSDUCER

PRODUCT DATA
from
FLOW TECHNOLOGY, INC.

4250 EAST BROADWAY ROAD ■ P.O. BOX 21346 ■ PHOENIX, ARIZONA 85036 ■ PHONE (602) 268-8776 ■ TELEX 668-344

OMNIFLO® TURBINE FLOW TRANSDUCERS

- FLUID FLOW RATES AS LOW AS 0.001 GPM
- MEASURES EITHER GASES OR LIQUIDS
- PULSE SIGNAL OUTPUT
- AVAILABLE IN A WIDE VARIETY OF MATERIALS
- EXTREME TEMPERATURE RANGE OF —430°F to +350°F
- HIGH PRESSURE CAPABILITY TO 5000 PSI



PRINCIPLE OF OPERATION

Flow Technology's "Omniflo" represents an outstanding achievement in the realm of ultra-low-level fluid flow measurement. The "Omniflo" turbine flow transducer is an in-line metering device utilizing a bladed rotor to generate digital flow information. There is an obvious similarity between the "Omniflo" and conventional turbine flow transducers; however, the "Omniflo" differs in several important aspects in its mode of operation.

Within the "Omniflo" meter a precision orifice directs all of the measured fluid tangentially past the underside of a paddle bladed rotor. The rotor responds by rotating in a plane in line with the fluid's motion in much the manner of an undershot water wheel. The "Omniflo's" turbine rotor, being freely suspended and of low mass, has effectively no ability to either absorb energy from, nor inject it into the moving fluid, so it must rotate at a speed which perfectly characterizes the velocity of the flowing fluid. A magnetic pick-off coil, located externally but adjacent to the rotor, has generated within it an electric current whose frequency is directly proportional to the rotation of the rotor and in turn proportional to fluid flow. The frequency of the generated pulses is proportional to the flow rate, and the sum of the pulses corresponds to the total fluid volume measured. These pulses can be fed directly into digital totalizers, frequency-to-DC converters, and, in fact, into any one of many frequency indicating, recording and control devices available within the field.

The unique character of the "Omniflo" is its ability to measure very low liquid and gas flow under high temperature and pressure conditions and to do this with accuracy and reliability.

GENERAL SPECIFICATIONS

FREQUENCY OUTPUT

The output of the "Omniflo" is a series of electrical pulses generated within its pick-off coil. The frequency range of these pulses will normally be within 2 to 1,000 Hz., supplied at a minimum level of at least 15 milivolts peak-to-peak.

CONNECTIONS

Standard fluid end fittings of the "Omniflo" are ½" AN-10050-8 or ½" female NPT. The electrical pick-off connector mates with an MS3106-10SL-4S two pin connector. The mating connector is furnished. Special connectors for either the fluid or electrical connections can be furnished upon request.

TEMPERATURE

Standard "Omniflo" transducers may be operated over a temperature range of −430°F to +350°F. Temperature rating to +750°F available with reduced performance.

MATERIALS

Standard "Omniflo" housings are fabricated of 303 stainless steel. Transducers to meet special requirements have been fabricated of aluminum, 316 and 347 stainless steels, Hastalloy, K-Monel, and PVC. An extensive selection of bearing materials and types are available – graphitar or carbide journals, ball bearings, or vee-jewel pivot bearings, for example.

PRESSURE

Fluid end connections are the governing factors in determining the "Omniflo's" pressure limitation. The standard transducer can operate with a fluid pressure of 5,000 psi at 100°F.

LOW FLOW – SPECIAL REQUIREMENTS

In order to sense and measure flow rates below 0.01 GPM liquid or 0.05 ACFM gas, the "Omniflo" must utilize an LFA (Low Flow Amplifier.) The LFA is normally supplied within its own enclosure and is used as a pre-amplifier between the "Omniflo" pick-off and the readout. See bulletin REA for details.

MEASUREMENT CHARACTERISTICS

LIQUID

REPEATABILITY

Within a normal 10 to 1 liquid flow range, the "Omniflo" will operate with a repeatability to within ±0.1% of reading.

LINEARITY

The performance of an "Omniflo" turbine meter is inherently non-linear. The degree of non-linearity is dependent upon the range of the particular meter selected and upon the viscosity of the fluid in which it will operate. Linearity characteristics for low viscosity fluids, (approximately 1 centistoke) are shown on bulletin TD-023-761.

Optional premium linearities are available for ball bearing "Omniflos" with flow rates above 0.1 GPM and ranges no greater than 10 to 1 operating in fluids with viscosities less than 3 centistokes.

FLOW RATE RANGE

The overall measurement capability of the "Omniflo" series covers the entire flow range of 0.001 to 5.0 gpm. Individual transducers are normally supplied to measure any specified 10 to 1 segment within the 0.001 to 5.0 gpm flow range.

VISCOSITY

"Omniflo" transducers are calibrated with MIL-C-7024B calibration fluid and furnished with calibration data. Calibration at other viscosities and fluids can be furnished upon request. Maximum viscosity varies from 5 to 50 centistokes depending upon flow range.

PRESSURE DROP

The pressure drop, based on water, will not exceed 10 psi for the maximum normal flow rate of any given "Omniflo" transducer, but will vary as a function of density and viscosity. Pressure drop requirements can be met by proper sizing of the transducer. See TD-024-762.

GAS

REPEATABILITY

The basic repeatability of the "Omniflo" transducer in gas service is ±0.2% at all points within a normal 10 to 1 actual-volume flow range; however, when referring this measured volume to standard conditions, it must be remembered that the repeatability experienced becomes a function of the precision of the temperature and pressure measurements, in addition to the actual volume of flow.

LINEARITY

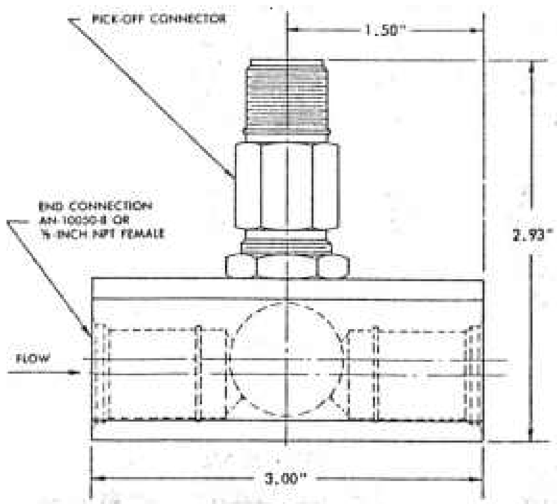
While "Omniflos" are basically non-linear, the linearity characteristics of "Omniflo" meters in gas are dependent upon the density of the gas as well as the flow range of the individual meter. Typical linearity characteristics for air at standard conditions are shown in bulletin TD-025. NO EXTENDED RANGES ARE AVAILABLE EXCEPT AS SHOWN ON TD-025.

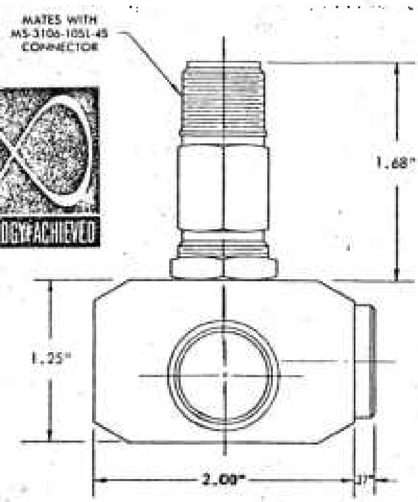
FLOW RATE RANGE

The "Omniflo" transducer being a volumetric measuring device senses only the actual-volume of the measured gas at the measurement point (at the turbine rotor). The overall actual-volumetric-flow rate range for gas is from 0.002 to 1.0 ACFM, with individual transducers being supplied to cover any specified 10 to 1 segment of this range. When calculating the relationship between the actual and standard condition volumetric flow range, normal temperature and pressure corrections must be used. Temperatures and pressures for the "Omniflo" should be taken immediately down-stream.

PRESSURE DROP

The gas density and viscosity largely determines the maximum pressure drop, however, under average conditions this should not exceed ½ psi. See TD-024-762.





APPENDIX B

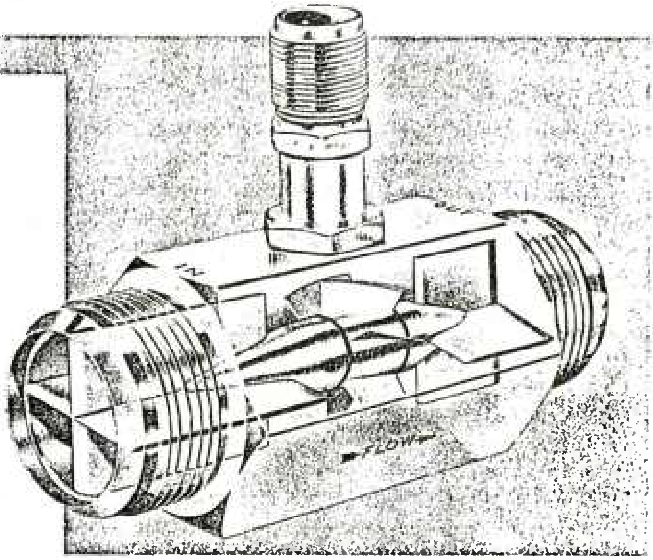
STANDARD LINE TURBINE FLOWMETER

PRODUCT DATA
from
FLOW TECHNOLOGY, INC.

4250 EAST BROADWAY ROAD ■ P.O. BOX 21346 ■ PHOENIX, ARIZONA 85036 ■ PHONE (602) 268-8776 ■ TELEX 668-344

STANDARD LINE TURBINE FLOWMETERS

- FLOW RATES FROM 0.03 TO 20,000 GALLONS PER MINUTE
- LIQUID OR GAS MEASUREMENT
- TEMPERATURES FROM —430°F. TO +750°F.
- HIGH ACCURACY
- DYNAMIC FLUID THRUST BEARING
- HIGH OVERSPEED CAPABILITY
- LOW MASS ROTOR FOR HIGH DYNAMIC RESPONSE, LONG BEARING LIFE
- WIDE CHOICE OF MATERIALS
- ADDED SAFETY OF BOTH UPSTREAM AND DOWNSTREAM ROTOR SUPPORTS
- LOW PRESSURE DROP



OVER 25 YEARS OF TURBINE FLOWMETER EXPERIENCE GOES INTO EVERY FTI TURBINE FLOWMETER

FLOW TECHNOLOGY, INC. engineers helped develop the first axial turbine flowmeters over 25 years ago. Because of continual development and improvement, FTI's turbine flowmeters have paced the state of the art. Fluid flow measurement is FTI's only business; we have to be very good at it.

GENERAL DESCRIPTION

Basically the FLOW TECHNOLOGY, INC. Standard Line Turbine Flowmeter is a miniature propeller suspended in a pipe. This freely-suspended axial turbine is rotated by the flow of fluid — gas or liquid — through the flowmeter. The rotational speed of the turbine if proportional to the velocity of the fluid. Since the flow passage is fixed, the turbine's rotational speed is also a true representation of the volume of fluid flowing through the flowmeter. This volume can be expressed as gallons per minute, liters per minute, cubic feet per minute, or various other engineering units.

This idea is very old. Flowmeters based on the water wheel, a similar principle, have been used for centuries. However, modern technology has developed the turbine flowmeter to an outstanding level of accuracy, linearity, durability and reliability.

There is no direct physical connection other than the turbine bearings between the turbine and its housing. The rotation of the turbine is sensed through the flowmeter body by an externally mounted pickoff on the surface directly above the flowmeter rotor. The rotation of this turbine rotor produces a train of electrical pulses in the pickoff. The frequency of these pulses is directly proportional to the volume flowrate. The pulses can then be transmitted to appropriate read-out electronics near the flowmeter or at a remote location. They can be amplified, counted, interfaced with computer terminals and used to measure and control fluid flow. The pulse train can be processed in any digital system.

It is necessary to translate the pulses into meaningful information. Flow Technology, Inc. manufactures a complete line of electronic devices for that purpose. These units can display flow rate in any engineering units, either analog or digital. There are also digital totalizers with LED or mechanical counters as well as batch controllers and blind converters which change signals into a format required to interface a customer's built in system.

GENERAL SPECIFICATIONS

(* Terminology per ANSI C85.1 and ISA S37.1)

ACCURACY: *

±0.05% at all points in the linear flow range (liquid)

± ½ % (gas)

LINEARITY: *

±0.5% of reading over the normal 10:1 range (liquid)

±0.1% special premium linearity for special pre-selected ranges. (liquid)

±1% of full scale (gas)

ELECTRICAL OUTPUT:

The output level conforms with ISA RP 31.1 and is a minimum of 30 mV peak-to-peak for frequencies at the bottom of the nominal flow range.

PRESSURE DROP:

Ask for Technical Data Report TD-109.

CALIBRATION:

Each turbine flowmeter is furnished with a calibration with the standard reference fluid, MIL-C-7024B. Special calibrations available for applications where viscosity varies considerably.

OPERATING PRESSURE:

In general, the limiting factor governing the operating pressure of an FTI Standard Line turbine flowmeter is the rating of the end connectors. Because there is no porting of the flowmeter body, the flowmeter can be constructed to handle exceptionally high pressures if desired.

DYNAMIC RESPONSE:

3 millseconds or better response to step input change of flow rate for meters smaller than 1 ½ inches, increasingly longer response times as the size of the meter and the mass of the rotor increases.

END CONNECTIONS:

Flowmeters FT-8 through FT-32 available with either AN Series 37° flared tube (MS-33656) or NPT end connections. Sizes FT-8 through FT-224 available with ASA B 16.5 flanges, 150 lb. through 2500 lb. ratings. Other end connections available on request.

ELECTRICAL CONNECTIONS:

AN3102A-10SL-4P with mating connector supplied. Flowmeters with explosion-proof pickoffs terminate in ½" conduit union.

MATERIALS:

All portions of FTI Standard Line turbine flowmeters that come into contact with the fluid are fabricated of 300-series and 400-series stainless steels. An extremely wide choice of materials is available to satisfy even the most severe specifications. See Options.

OPERATING TEMPERATURE RANGE:

FTI Standard Line turbine flowmeters can be fabricated to measure fluids within a temperature range of —430°F. to +750°F. Nominal temperature range determined by pickoff selected. See bulletin No. PO-761.

APPLICATIONS OF THE TURBINE FLOWMETER

ENGINE R & D:

Extreme precision flow rates of fuels and oxidizers for rocket and jet engine testing and today's urgent requirements for the same measurements for internal combustion and Diesel engine pollution testing.

POLLUTION CONTROL:

Precise measuring and control of fuel oils and natural gas to combustion turbine electric generating units allows conservation of energy resources and more efficient operation.

ON-LINE BLENDING:

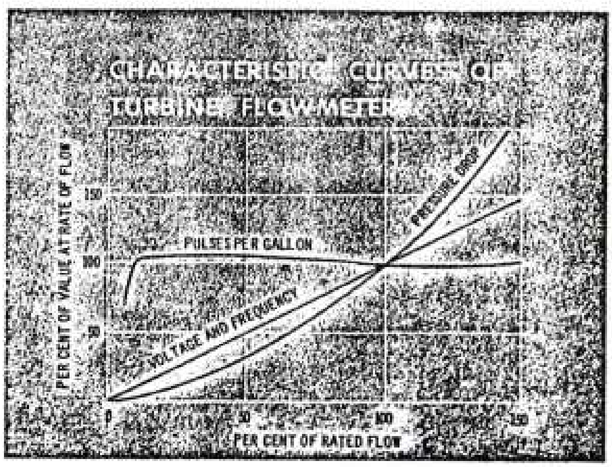
In the petrochemical and chemical industries, turbine flowmeters are precisely measuring catalysts and other fluids to insure the highest quality control and the lowest possible waste in automated systems.

BATCH CONTROL:

Turbine flowmeters are accurately measuring exact batches of liquids with a consistency and reliability vastly superior to weighing and other techniques.

FLOW MONITORING:

The output of turbine flowmeters is being used to monitor critical flow rates of both liquids and gases in a number of different industrial processes, protecting pumps and other equipment as well as insuring consistent end products.



SIZES & SPECIFICATIONS
LIQUID

Model No.	Nominal End Fitting Size (In.)	Normal Flow Range (U.S. GPM) Minimum	Normal Flow Range (U.S. GPM) Maximum	Extended Flow Range (U.S. GPM) Minimum* Journal	Extended Flow Range (U.S. GPM) Minimum* Ball	Extended Flow Range (U.S. GPM) Maximum	Approximate** Frequency Output (CPS)	Approximate "K" Factor Pulses Per Gallon
FT-4-8	½	0.25	2.5	0.06	0.03	3	2300	55000
FT-6-8	½	0.5	5.0	0.1	0.05	5	2100	25000
FT-8-8	½	0.75	7.5	0.16	0.08	8	2000	16000
FT-8	½	1.0	10.0	0.2	0.1	10	2000	12000
FT-10	⅝	1.25	12.5	0.2	0.15	15	1700	8300
FT-12	¾	2.0	20	0.33	0.25	25	2000	6000
FT-16	1	5.0	50	0.6	0.6	60	2000	2400
FT-20	1¼	9.0	90	0.9	0.9	90	1950	1300
FT-24	1½	15	150	1.5	1.5	150	1500	600
FT-32	2	20	225	2.5	2.5	250	1300	350
FT-40	2½	30	400	4.5	4.5	450	650	100
FT-48	3	40	650	7.5	7.5	750	812	75
FT-64	4	75	1250	15	15	1500	625	30
FT-80	5	90	2000	25	25	2500	300	9
FT-96	6	130	3000	35	35	3500	***	***
FT-128	8	250	5500	60	60	6000	***	***
FT-160	10	400	8500	100	100	10000	***	***
FT-192	12	550	12000	150	150	15000	***	***
FT-224	14	750	16000	200	200	20000	***	***

Other sizes available; check with factory.
The above data is based on a liquid with a S.G. of 1 and a viscosity of 1 centistoke.
Flow Rates and Frequencies other than shown available upon request.

* The extended range requires an active (RF) pickoff and a Range Extending Amplifier Model LFA-300 for meters 2" and smaller.
** At maximum of normal flow range. *** Consult factory.

SIZES & SPECIFICATIONS
GAS

Model No.	Nominal End Fitting Size (In.)	Normal Flow Range (ACFM) Minimum	Normal Flow Range (ACFM) Maximum	Extended Flow Range (ACFM) Minimum	Extended Flow Range (ACFM) Maximum	Approximate** Frequency Output (CPS)	Approximate "K" Factor Pulses Per Cu. Ft.
FT-4-8	½	0.25	2.5	0.2	3	2300	55000
FT-6-8	½	0.5	5.0	0.25	5	2100	25000
FT-8-8	½	0.75	7.5	0.4	8	2000	16000
FT-8	½	1.0	10.0	0.5	10	2000	12000
FT-10	⅝	1.25	12.5	0.6	15	1700	8300
FT-12	¾	2	20	1.0	25	2000	6000
FT-16	1	5	50	1.5	60	2000	2400
FT-20	1¼	9	90	2.25	90	1950	1300
FT-24	1½	15	150	3.75	150	1500	600
FT-32	2	20	225	5	250	1300	350
FT-40	2½	30	400	9	450	650	100
FT-48	3	40	650	15	750	812	75
FT-64	4	75	1250	30	1500	625	30
FT-80	5	90	2000	50	2500	300	9
FT-96	6	130	3000	70	3500	***	***

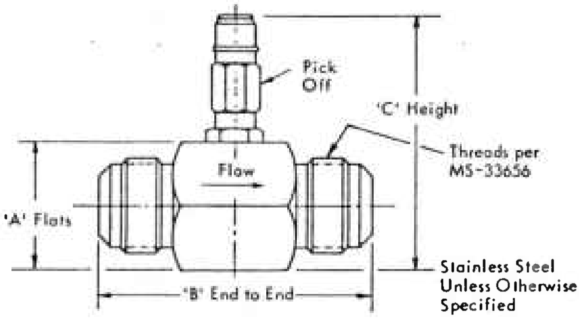
The above data is based on air at 60°F. and 14.7 psi for meters with ball bearings.
** At maximum of normal flow range. *** Consult factory.

Gases with less density will have a more limited range.

DIMENSIONS

All dimensions in inches — certified dimensians avai:able an request.

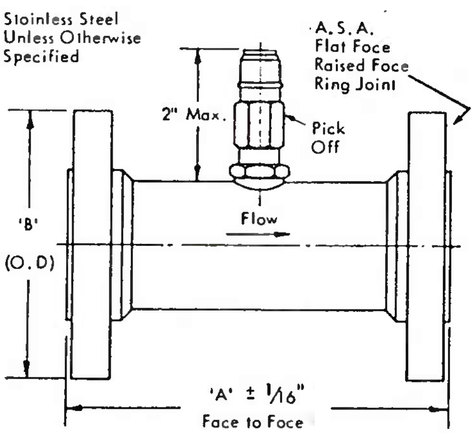
AN (MS-33656) or NPT
NPT (consult factory for larger size NPT meter)



SIZE & MODEL		A	B	C
¼" — ⅜" — ½"	FT-8M	1" sq.	2.45	3.00
⅝"*	FT-10M	1.312	2.72	3.187
¾"	FT-12M	1.375	3.25	3.250
1"	FT-16M	1.625	3.56	3.5
1½"	FT-24M	2.125	4.59	4.375
2"	FT-32M	2.750	6.06	4.750

* NPT meter hos 3/4" end fittings.

END FLANGED (ASA B16.5):



SIZES (1/2" - 14")

LINE SIZE	150# ANSI		300# ANSI		400# ANSI		600# ANSI		900# ANSI		1500# ANSI		2500# ANSI	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
.5	5.0	3.5	5.0	3.75	5.0	3.75	5.0	3.75	7.0	4.75	7.0	4.75	7.0	5.25
.63	5.5	3.88	5.5	4.63	5.5	4.63	5.5	4.63	7.0	5.13	7.0	5.13	7.0	5.5
.75	5.5	3.88	5.5	4.63	5.5	4.63	5.5	4.63	7.0	5.13	7.0	5.13	7.0	5.5
1.0	5.5	4.5	5.5	4.88	5.5	4.88	5.5	4.88	8.0	5.88	8.0	5.88	8.0	6.25
1.25	6.0	4.63	6.0	5.25	6.0	5.25	6.0	5.25	8.0	6.25	8.0	6.25	8.0	7.25
1.5	6.0	5.0	6.0	6.13	6.0	6.13	6.0	6.13	9.0	7.0	9.0	7.0	9.0	8.0
2.0	6.5	6.0	6.5	6.5	6.5	6.5	6.5	6.5	9.0	8.5	9.0	8.5	9.0	9.25
2.5	7.0	7.0	7.0	7.5	7.0	7.5	7.0	7.5	10.0	9.63	10.0	9.63	10.0	10.5
3.0	10.0	7.5	10.0	8.25	10.0	8.25	10.0	8.25	10.0	9.5	10.0	10.5	10.0	12.0
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4.0	12.0	9.0	12.0	10.0	12.0	10.0	12.0	10.75	12.0	11.5	12.0	12.25	12.0	14.0
5.0	14.0	10.0	14.0	11.0	14.0	11.0	14.0	13.0	14.0	13.75	14.0	14.75	14.0	16.50
6.0	14.0	11.5	14.0	12.5	14.0	12.5	14.0	14.0	14.0	15.0	—	—	—	—

Consult Foctory for dimensions if meter is over 6".

Optionol 1" NPT pipe connection ovoiloble for Explosion-Proof electricol hook-up (FT-24 & lorger).

Refer ta PMNS-772 for complete model no. informatian.

OPTIONS

- Speciol end fittings as required.
- Bi-directianal flaw.
- Speciol materiols — oluminum, 316 stainless steel, 347 stainless steel, hastollay, K-Monel, Titonium, ond PVC material avoiloble.
- Speciol beorings — corbide, grophite, ar Rulan journals.
- Pickoff coils — Inductive, reluctonce, high temperature (to +750°F.), madulated rf 400°F. ond explasian-proof.
- Speciol and odditianal calibratians available.

FOR ADDITIONAL INFORMATION
CONTACT FTI OR YOUR FTI REPRESENTATIVE:

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215 North 17th Street
Omaha, NE 68102

U.S. Army Engineer District, Kansas City (2)
ATTN: Construction Division
700 Federal Building
Kansas City, MO 64106

U.S. Army Engineer District, Sacramento
ATTN: Construction Division
650 Capitol Mall
Sacramento, CA 95814

U.S. Army Engineer District, Huntsville (3)
ATTN: Construction Division
P.O. Box 1600 West Station
Huntsville, AL 35807

Commander
Badger Army Ammunition Plant
ATTN: SARBA-CE
Baraboo, WI 53913

Commander
Cornhusker Army Ammunition Plant
ATTN: SARCO-E
Grand Island, NB 68801

Commander
Holston Army Ammunition Plant
ATTN: SARHO-E
Kingsport, TN 37662

Commander
Indiana Army Ammunition Plant
ATTN: SARIN-OR
Charlestown, IN 47111

Commander
Naval Weapons Support Center
ATTN: Code 5042, Mr. C. W. Gilliam
Crane, IN 47522

Commander
Iowa Army Ammunition Plant
ATTN: SARIO-A
Middletown, IA 52638

Commander
Joliet Army Ammunition Plant
ATTN: SARJO-SS-E
Joliet, IL 60436

Commander
Kansas Army Ammunition Plant
ATTN: SARKA-CE (5)
Parsons, KS 67537

Commander
Lone Star Army Ammunition Plant
ATTN: SARLS-IE
Texarkana, TX 57701

Commander
Longhorn Army Ammunition Plant
ATTN: SARLO-O
Marshall, TX 75670

Commander
Louisiana Army Ammunition Plant
ATTN: SARLA-S
Shreveport, LA 71102

Commander
McAlester Army Ammunition Plant
ATTN: SARMC-FD
McAlester, OK 74501

Commander
Milan Army Ammunition Plant
ATTN: SARMI-S
Milan, TN 38358

Commander
Newport Army Ammunition Plant
ATTN: SARNE-S
Newport, IN 47966

Commander
Pine Bluff Arsenal
ATTN: SARPB-ETA
Pine Bluff, AR 71601

Commander
Radford Army Ammunition Plant
ATTN: SARRA-EN
Radford, VA 24141

Commander
Ravenna Army Ammunition Plant
ATTN: SARRV
Ravenna, OH 44266

Commander's Representative
Sunflower Army Ammunition Plant
Box 640
ATTN: SARSU-O
De Soto, KS 66018

Commander
Volunteer Army Ammunition Plant
ATTN: SARVO-T
Chattanooga, TN 34701

Weapon System Concept Team/CSL
ATTN: DRDAR-ACW
Aberdeen Proving Ground, MD 21010

Technical Library
ATTN: DRDAR-CLJ-L
APG, Edgewood Area, MD 21010

Director
U.S. Army Ballistic Research Agency
ARRADCOM
ATTN: DRDAR-TSB-S
Aberdeen Proving Ground, MD 21005

Benet Weapons Laboratory
Technical Library
ATTN: DRDAR-LCB-TL
Watervliet, NY 12189

Dr. John A. Brown
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U.S. Army Materiel Systems Analysis Activity
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